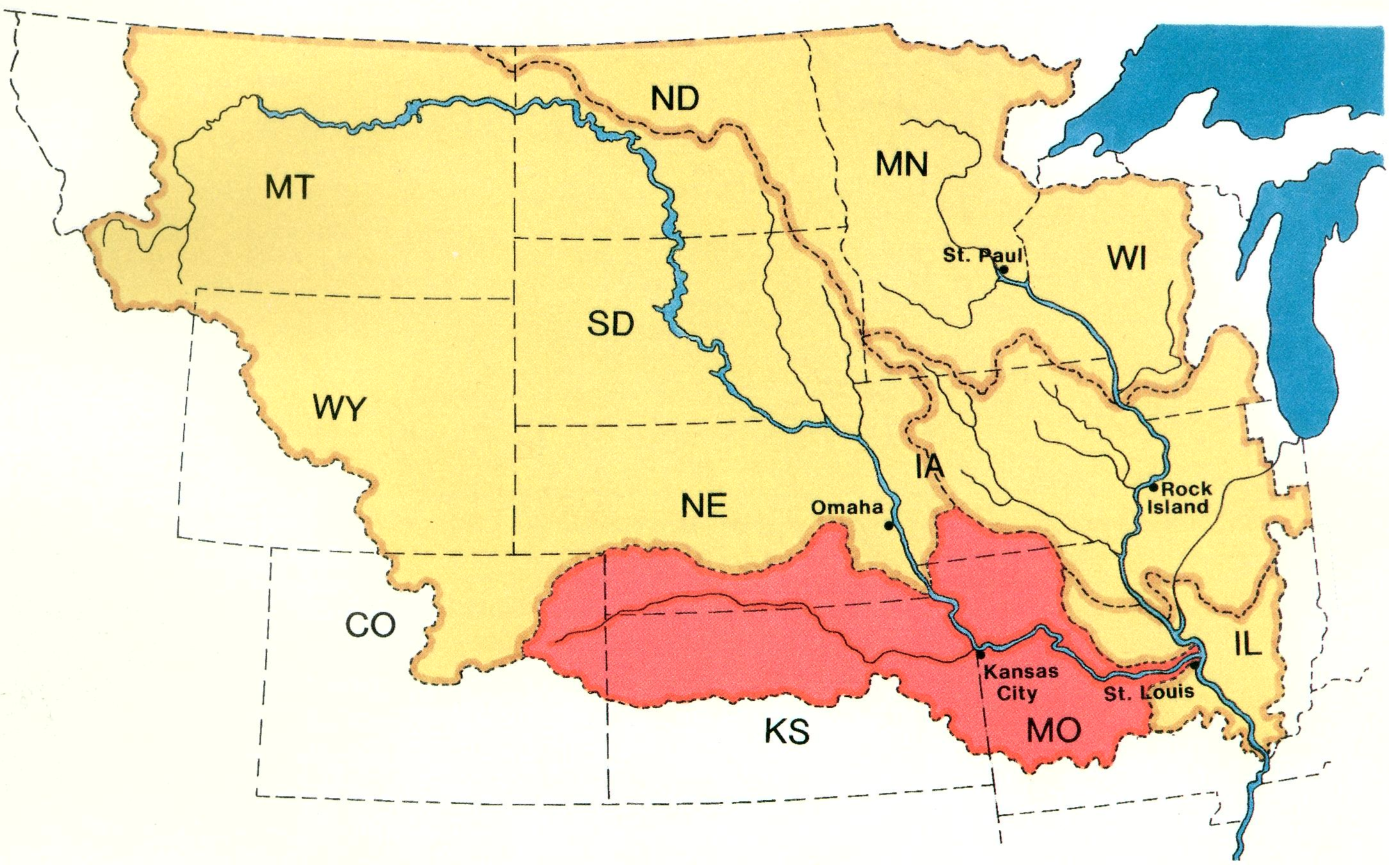
# The Great Flood of 1993 Post-Flood Report

## Lower Missouri River Basin




# Appendix E

September 1994

US Army Corps of Engineers
Kansas City District

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# The Great Flood of 1993
# Post Flood Report
# Lower Missouri River Basin
# Kansas City District

## I. Introduction

### A. Authority

This report covers floods which occurred within the boundaries of the Kansas City Engineer District (the District) from March through August of 1993. It has been prepared in accordance with ER 500-1p and the Kansas City District Natural Disaster Procedures. Specific authority for preparing this report was provided by HQUSACE letter to Division Engineer, North Central Division, dated 18 August 1993, subject, Post Flood Report, Mississippi River Basin and Tributaries Flooding, 1993.

### B. Purpose and Scope

The objective of the Post Flood Report is to present an accurate picture of the Great Flood of 1993 in the District for use in the analysis of the flood control protection system on the Lower Missouri River and tributaries. Included in the report is a description of the:

1) flood conditions which existed in the Lower Missouri River basin during 1 March through 31 August 1993;

2) flooding which occurred;

3) nature of the District emergency activities undertaken;

4) actual damages and damages prevented by District projects;

5) data collected and recorded for future reference in:

    a) future flood control studies, water control management, engineering, and design;

    b) improving proficiency during future flood emergencies; and

6) lessons learned.

## C. Description of the Lower Missouri River Basin, Kansas City District

1. Physical Characteristics

The Missouri River basin is the biggest of the Nation's 18 major water resource regions, embracing 513,000 square miles within the United States including all or parts of 10 states. The basin also includes 9,715 square miles in Canada. On the west are the Rocky Mountains, and on the east are the productive farmlands of the Missouri-Mississippi drainage areas. The Missouri River flows in a southeasterly direction 2,315 miles from its headwaters at Three Forks, Montana, through six major main stem reservoirs to its confluence with the Mississippi about 15 miles above St. Louis, Missouri. The Kansas City District portion of the Missouri River basin includes all of the lower basin drainage area from Rulo, Nebraska, at river mile 498.1 to the mouth near St. Louis, Missouri. The Omaha District has responsibility for the basin area upstream of the Kansas City District. The Kansas City District includes portions of the states of Missouri, Iowa, Kansas, Nebraska, and Colorado as shown on Plate 1. The drainage area within the Kansas City District amounts to 110,445 square miles. In the upper portion of the District, the Missouri River flows through the dissected till plains of the central lowlands to Kansas City, and then along the northern border of the Osage Plains and the Ozark Plateau to a point near St. Charles, Missouri where it re-enters the central lowlands to join the Mississippi River. Elevations vary from about 5,000 feet, mean sea level (ft., m.s.l.) on the High Plains of eastern Colorado, to about 400 ft., m.s.l. on the bottomlands at the mouth.

2. Climate

Significant variations in the climate occur within the lower basin. The eastern part lies within the humid climatic zone. Moving west the climate becomes less humid so that, at the western part of the lower basin, in the High Plains Region, the climate zone is semi-arid. Generally, summers are hot and winters are comparatively moderate. The climate is continental in type, being characterized by wide ranges in temperature and irregular annual and seasonal precipitation.

a. Precipitation

The annual precipitation increases from west to east, from about 16 inches in the High Plains of eastern Colorado to over 40 inches in the Ozark Plateaus in the south central part of Missouri. The Missouri River basin, as a whole, has an average annual precipitation of about 20 inches. Most precipitation occurs as rainfall during the growing season, but Missouri River flows can be heavily influenced by snowmelt runoff from outside the District. Rainstorms within the District can be very intense as shown by the world record accumulation of 12 inches within 42 minutes near Holt, Missouri on 22 June 1947. Plate 2 shows the locations of precipitation and stream gaging stations.

b. Temperature

Extremes in temperature are induced by alternating cold air masses moving in from the north and northwest and warm air masses moving from the Gulf regions. Under their influences the seasonal variation, and even the daily range in temperature, tend to be large. All localities have experienced summer temperatures over 100º F. and winter temperatures well below 0º F. Average daily maximum January temperatures are above freezing throughout the District portion of the basin. Average daily maximum July temperatures are about 90º F. The mean length of freeze free period of the year varies from about 150 days in the western part of the lower basin to over 180 days in the eastern part.

3. Hydrology

Streams in the lower Missouri River basin generally have moderate to high flows during the spring and fall months coinciding with the months of heaviest precipitation. Flows taper off during the summer and winter months except for the relatively short duration high flows caused by summer storms or, on rare occasion, winter snowmelt. Streams in the Ozarks Plateaus have significant groundwater flow because of the numerous springs in the area. Mean annual runoff varies from about one inch in the western part of the lower basin to about 12 inches in the east. However, streamflows vary greatly due to extreme differences in long term precipitation patterns as well as high intensity rainstorms. Average annual discharge for the Missouri River at the lowermost gaging station at Hermann, Missouri is 55.5 million acre-feet (MAF), but prior to 1993, had varied from a low of 21.5 MAF in 1934 to 101.6 MAF in 1973. The 1993 runoff amounted to 131.4 MAF.

4. Economic Development

The lower basin contains a broad range of economic characteristics. The economic development has been strongly related to its geographic location, climatic conditions, and the availability of natural resources. These natural attributes have enabled a diverse economy to develop and flourish including agricultural, commercial, utility, industrial, transportation, and urban endeavors. A diverse transportation system includes a 9-foot Missouri River navigation channel, an extensive rail network, state and interstate highways, and commercial airlines.

5. Water Resources Development

The major rivers in the District include the Missouri River and its tributaries: the Kansas with its principal tributaries, the Republican, Smoky Hill, Big Blue and Delaware Rivers; the Platte (in Missouri and Iowa); the Grand; the Chariton; the Osage-Marais des Cygnes; and the Gasconade. Water resources in the District have been extensively developed through the programs of the Corps of Engineers and the Bureau of Reclamation

(Bureau). The Corps of Engineers has 18 multiple purpose lake projects in operation. All of these projects are operated for flood control. Other purposes may include municipal water supply, generation of hydroelectric power, low flow water quality releases, irrigation, recreation, and fish and wildlife. Table 1 lists the Corps projects.

**Table 1**
**Corps of Engineers Lake Projects**
**Kansas City District**

| Project Name | River and State |
|---|---|
| Smithville Lake | Little Platte River, MO |
| Harlan County Lake | Republican River, NE |
| Milford Lake | Republican River, KS |
| Kanopolis Lake | Smoky Hill River, KS |
| Wilson Lake | Saline River, KS |
| Tuttle Creek Lake | Big Blue River, KS |
| Perry Lake | Delaware River, KS |
| Clinton Lake | Wakarusa River, KS |
| Longview Lake | Little Blue River, MO |
| Blue Springs Lake | East Fork Little Blue River, MO |
| Rathbun Lake | Chariton River, IA |
| Long Branch Lake | East Fork Little Chariton River, MO |
| Melvern Lake | Marais des Cygnes River, KS |
| Pomona Lake | Hundred and Ten Mile Creek, KS |
| Hillsdale Lake | Big Bull Creek, KS |
| Stockton Lake | Sac River, MO |
| Pomme de Terre Lake | Pomme de Terre River, MO |
| Harry S. Truman Dam and Reservoir | Osage River, MO |

The Bureau operates 11 lake projects in the District primarily for the storage and distribution of water for irrigation, but which include storage for flood control over which the Corps of Engineers exercises responsibility for operation as part of the lower Missouri flood control system. The Bureau lakes are listed in Table 2. The District and Bureau lake projects are shown on Plate 1.

**Table 2**
**Bureau of Reclamation Lake Projects**
**Kansas City District**

| Project Name | River and State |
|---|---|
| Bonny Dam and Reservoir | South Fork Republican River, CO |
| Swanson Lake (Trenton Dam) | Republican River, NE |
| Enders Dam and Reservoir | Frenchman Creek, NE |
| Hugh Butler Lake (Red Willow Dam) | Red Willow Creek, NE |
| Harry Strunk Lake (Medicine Creek Dam) | Medicine Creek, NE |
| Keith Sebelius Lake (Norton Dam) | Prairie Dog Creek, KS |
| Lovewell Dam and Reservoir | White Rock Creek, KS |
| Cedar Bluff Dam and Reservoir | Smoky Hill River. KS |
| Kirwin Dam and Reservoir | North Fork Solomon River, KS |
| Webster Dam and Reservoir | South Fork Solomon River, KS |
| Waconda Lake (Glen Elder Dam) | Solomon River, KS |

A number of privately owned lake projects are located within the District. The most significant of these is the Lake of the Ozarks formed by Bagnell Dam. The dam is located on the Osage River about 93 miles downstream of the Corps' Truman Dam. Bagnell Dam and the Lake of the Ozarks constitute a single purpose project owned by Union Electric Company and is operated for the primary purpose of hydroelectric power generation. Permanent and second home developments as well as tourist attractions at the Lake of the Ozarks make it a regional attraction for the area.

The District has constructed levee and/or channel improvement projects which provide flood protection at 51 locations. Of the 51 locations, 15 are levees constructed as part of the Missouri River Levee System (MRLS). All of the completed MRLS units, except four, are upstream of Kansas City. Some of the local protection projects have several units which contribute to the flood protection at that location. For instance, at the Kansas Citys along the Kansas and Missouri Rivers, there are seven separate levee units; Argentine, Armourdale, Central Industrial District (CID), Fairfax, North Kansas City, Northeast (East Bottoms), and Birmingham. Similarly, at Topeka, Kansas, there are four separate levee units and a major channel diversion project.

The Missouri River Bank Stabilization and Navigation Project between Sioux City, Iowa and the mouth, traverses the 498.1 river miles within the District, plus 233.9 miles in the Omaha District. This project entails the use of bank revetments and dikes to achieve a free flowing navigation channel. In addition, a fish and wildlife mitigation project is currently underway to compensate for the adverse impacts caused by the bank stabilization and navigation project.

Flows on the Missouri River within the District are substantially affected by the six main stem lake projects in the Omaha District. The main stem projects filled for the first time in 1967. These six Corps lakes regulate runoff from the entire upper half of the Missouri River basin. The system, composed of Fort Peck Dam in Montana, Garrison Dam in North Dakota, Oahe, Big Bend, Fort Randall, and Gavins Point Dams in South Dakota can store 73.9 million acre-feet of water. Within that storage space, 16.3 million acre-feet are devoted exclusively to flood control, and an additional 11.6 million acre-feet are available for flood control on a seasonal basis.

## II. Synopsis of the Flood

### A. Antecedent Conditions

The 1993 Flood affected a large portion of the northcentral and midwest United States. The Mississippi River above St. Louis and the Missouri River downstream of Omaha, NE and many of the tributaries of these two rivers experienced record setting river stages. Floods of this magnitude and areal extent result from unusual weather patterns which persist over a long period of time. Starting in the fall of 1992 and continuing through the winter and into 1993, precipitation throughout much of the District was above average with some areas recording twice the normal amount for most of the fall and winter months. This caused saturated soil conditions and higher than normal streamflows going into the spring of 1993.

### B. Storm Pattern

The storm pattern is described in detail in the Rock Island District report on the 1993 Flood, and is summarized here.

> The weather pattern that predominated the mid-western states during the winter months was a split flow pattern that is typical of El Nino events. At the jet stream level, the westerly air flow became split by a high pressure ridge over the western United States. The subtropical jet stream forced itself well to the south of the ridge into southern California while the polar jet stream was pushed to the north of the ridge into northwestern Canada. Those two rapidly moving streams of air swung around the eastern side of the high pressure ridge and converged over the midwest. This produced ideal conditions for the creation of significant precipitation.

The weather pattern that predominated in the summer months was the result of a large dome of stationary high pressure (commonly called the Bermuda High) in the upper atmosphere that remained over the southeastern United States. The high pressure area was responsible for droughts in the south and east and for a major heat wave experienced along the eastern seaboard in July. The circulation pattern pushed moisture from the Gulf up into the midwest. At the same time, a strong low pressure system was present in the upper atmosphere in the northern Rockies. This stationary system was responsible for the unseasonably cold weather that much of the mountain west experienced during the summer. Unfortunately the midwest was located at the boundary system between the two systems. The high pressure system brought the warm and humid air into the region while the low pressure system continued to spin off disturbances across the plains that generated the thunderstorms. The exact demarcation between the two weather systems changed continually which explains why the heavy rains also changed locations. This pattern was initially noticed in mid-June and did not break up until mid-August.

**C. Flood Sequence**

This discussion of the flood sequence includes a summarized chronology of events taken from the situation reports produced by the Emergency Operations Center (EOC). The sequence shows that the wet spring resulted in the Missouri River rising above flood stage in early May and navigation being suspended from river miles (RM) 197.0 to 354.0 But, by 16 May, the river was reopened to navigation and the flood condition ended on 20 May. This relatively minor event set the stage for a series of events that would result in record flows and stages on the Missouri River and record pool levels at several lake projects within the District during the months of July and August. Even after the record setting flood had passed out of the Missouri River basin, during August and September there continued to be rainfall that caused recurrences of flooding in localized areas. Also, there were many threats of rainfall that kept interfering with the gigantic task of post flood cleanup and rehabilitation.

1. May-Week 2

The first event of the 1993 Flood for the District started in the second week of May. Two Federal levees, MRLS L-246 and Lower Chariton Levee System near RM 239 to 250, began experiencing sloughing and slides as a result of the saturated ground conditions from the continuous rain. Flood watches were issued for central and eastern portions of central and northcentral Kansas. A slow moving upper level system continued to pump abundant moisture into the regions.. On 12 May, the U. S. Coast Guard closed the Missouri River to navigation from RM 197.0 to 354.0. The State of Kansas reported evacuation of approximately 100 families from an area in Ogden, Kansas. High pools required increased dam safety surveillance at eight District lake projects, and critical surveillance at Clinton Lake.

2. May-Week 3

A non-Federal levee on the Missouri River, known as the Cambridge Levee Association, RM 235.4 to 231.0, failed. Field personnel reported that most, if not all, exterior (riverward) secondary levees had been overtopped from RM 329 (Napoleon, MO) to RM 142 (Jefferson City, MO). The sponsor of the North Kansas City Levee reported that major ground settlement had occurred near the south pumping station of the airport section. It was determined that a discharge line from the pump station to the river had broken and was causing ground subsidence in the south wall of the pump station. On 16 May, the river was reopened to navigation. On 17 May, the Clinton Lake flood pool reached a record elevation of 887.7 ft., m.s.l. The flood condition ended on 20 May.

3. July-Week 1

On 3 July, a flood emergency was declared to exist within the Kansas City District. Flooding conditions existed along the entire Missouri River within the District. At St. Charles, MO, the river rose above flood stage. The Grand, Platte, Smoky Hill and Blackwater Rivers were also at flood stage. Liaison was established with the Rock Island and St. Louis Districts to coordinate ongoing activities and requirements within the State of Missouri. The U. S. Coast Guard closed portions of the river.

On 5 July, strong thunderstorms occurred over northeast Kansas and northwest Missouri. Widespread rainfall amounts of one inch or more were reported. Precipitation totals as high as 5.15 inches were reported in Kansas. Unofficial rainfall reports in Holt County, Missouri ranged from 4 to 7 inches overnight. The State of Kansas reported evacuation of 20 families in Nemaha County due to flooding on the South Fork of the Big Nemaha River. A District liaison officer was dispatched to the State of Missouri's Emergency Operations Center in Jefferson City, MO.

Rainfalls of 7 and 8 inches fell in the Jefferson City and Hermann, MO areas, respectively, the evening of 6 July. The first crest of the river was occurring at those locations and the heavy rains aggravated the situation. Liaison was established with the State of Iowa Emergency Management Agency. Aerial reconnaissance of the Missouri River, Jefferson City to the mouth, showed three primary levees had breached and seven primary levees had been overtopped.

On 7 July, heavy downpours continued over portions of the Missouri River basin. Near record flooding was forecast or occurred on the Tarkio River near Fairfax, MO; Turkey Creek near Seneca, KS; Big Nemaha River near Falls City, NE; and 102 River near Bedford, IA. Flooding continued on the mainstem of the Missouri River from Nebraska City, NE downstream to St. Charles, MO. And the forecast called for possibly more heavy rains in places already hammered by heavy precipitation. Increased surveillance was initiated at Tuttle Creek, Milford, Perry, Kanopolis, Wilson, Smithville and Long Branch Lakes. Contingency plans for high river levels at the North Kansas City levee, airport section, were activated. A temporary ring levee was constructed as a result of the ground settlement problem identified during the May flood. Evacuations of residents in Hartsburg, Morrison, Pattonsburg, and North Jefferson City were accomplished.

4. July-Week 2

On 9 July, an additional 1,400,000 sandbags began to arrive to replenish the depleted stock. Rainfall amounts up to 2.3 inches fell in the District with the heaviest amounts occurring in the Smoky Hill and Solomon River basins. Forecasts indicated an additional 1 to 4 inches could occur between Kansas City and Omaha. Record stages were being experienced in the Grand River basin towns of Pattonsburg, Gallatin, Chillicothe, Sumner, and Brunswick, all in Missouri. Levee failures resulted in short-lived stage declines at Hermann and St. Charles. The State of Missouri submitted documentation for a Presidential Disaster Declaration in counties along the Missouri River. Surveillance was increased to the critical level at Rathbun Lake.

On 10 July, the Emergency Operations Center (EOC) initiated 24 hours a day operations. Overnight rain caused the Missouri River Kansas City stage to rise 2.5 feet higher than the previous day. Heavy rain fell between Lawrence, KS and Kansas City. Across the Kansas City metropolitan area rainfall of 2 to 5 inches was recorded, and there were unofficial reports of as much as 7 inches. Turkey Creek in Kansas City, KS and MO overflowed resulting in the closure of Interstate Highway 35 and other major streets. Flood flows from Turkey Creek spilled into the Central Industrial District. Streets in the vicinity of Brush Creek in Kansas City, MO were closed for a time. The Dredge Mitchell (no longer in Federal service) broke its moorings at the mouth of the Kansas River and made a spectacular, out of control, journey down the Missouri River, colliding with a barge, two railroad bridges and three highway bridges before being recovered by a commercial towboat about three miles downstream. High flood pool levels caused the closing of some or all public use areas at Tuttle Creek, Milford, Wilson, Kanopolis, Smithville and Rathbun Lakes.

On 12 July, District personnel met with the L-246 levee district officials to discuss flood fighting efforts. The levee district was reminded that L-246 was only designed to provide 25-year level of protection and that sandbagging efforts should be limited to low spots along the levee. Raising of the levee with sandbags could result in flooding at Brunswick, MO located just upstream of the levee.

On 13 July, additional flooding was reported in Boone, Holt and Anderson Counties in Missouri. The Governor of Kansas issued a disaster emergency proclamation for

Wyandotte County. The Missouri River inundated U. S. Highway 63, north of Jefferson City, cutting off its link with Columbia, MO and Interstate Highway 70.

On 14 July, a new flash flood watch was in effect for much of western Missouri because of overnight rainfall of 4.5 inches or more.

On 15 July, it was reported that near Missouri RM 232, three miles west of Glasgow, MO, the Gateway Western Railroad embankment had washed out and the river was threatening to change course. During the next few days, four U. S. Army Reserve Chinook helicopters moved roughly 750 tons of rock from a quarry about 5 miles away to the breach. Some of the stones weighed more than six tons. The operation successfully prevented bypassing the existing navigation channel. By this date, it was estimated that a majority of the non-Federal levee units along the Missouri River had been breached or overtopped. All of the non-Federal levee units along the Grand River had been breached or overtopped.

5. July-Week 3

On 16 July, a levee breach downstream of St. Charles, MO allowed the Missouri River to cut across the peninsula in the vicinity of Portage des Sioux to join the Mississippi River. The following day, President Clinton held a Flood Response Mobilization and Recovery briefing in Arnold, MO. Later in the day, heavy rains, ranging from one to five inches fell in the Republican and lower Kansas River basins. On 18 July, the District sent personnel to the EOCs in Manhattan, Junction City and a state EOC in Topeka, KS to assist local officials with identifying flood prone areas that could be impacted by increased releases from Tuttle Creek and Milford Lakes that were becoming necessary due to high pool levels. As of 18 July, over 1.7 million sandbags had been issued.

On 19 July, the District notified headquarters in Washington, DC that the situation in central Kansas worsened overnite. Heavy rains in the Fort Riley, Manhattan, and Junction City areas had caused increased runoff into Tuttle Creek and Milford Lakes. Increased releases from Milford Lake were begun immediately. State authorities issued evacuation notices to the downstream areas. By 20 July, Milford was at 103% of its flood control storage and Tuttle Creek was at 99.0%. Releases from Milford had to be reduced because of erosion in the left bank outlet channel downstream of the stilling basin.

On 21 July, Rathbun Lake was nearing a record flood pool elevation and water was approaching the spillway crest. Central Kansas reported 8-9 inches of rain causing evacuations during the night due to flash flooding. Kanopolis and Perry Lakes approached their spillway crests. Near record pools occurred at several projects. A letter contract was issued to construct a rock access road and reinforcement of the levee embankment on MRLS unit L-246 near Brunswick, MO.

6. July-Week 4

On 23 July, the entire town of Elwood, KS was evacuated because of the potential failure of MRLS R 471-460. Also, approximately 425 homes in Wyandotte County, KS were evacuated. Tuttle Creek Lake reached a record elevation of 1137.7 ft., m.s.l. Heavy rains continued over central and northern Missouri. Evacuations included Bean and Sugar Lakes in Platte County, Missouri City in Clay County, and Pattonsburg in Daviess County.

On 24 July, MRLS R 471-460, known as the St. Joseph Airport Levee, was overtopped near the old Missouri River channel, east of Rosecrans Airport. The Governor of Kansas was briefed at Perry Lake on the status of the lake's flood control storage and the Corps intentions to increase releases which would inundate downstream areas. The District's Real Estate Division prepared a form letter for use in responding to inquiries about making claims against the Government because of recent flooding. Topeka experienced severe problems with its wastewater treatment system and its water supply system was being threatened. The City of St. Joseph was also having problems keeping floodwater out of its water supply system. As of 24 July, the Red Cross was operating 16 shelters in Kansas.

On 25 July, the Milford Lake flood pool crested at a record level of 1181.9 ft., m.s.l. This was 5.7 feet higher than the uncontrolled spillway crest. The town of Weston, MO lost its water supply because the Missouri River inundated the treatment facility. St. Joseph, MO shut down its water supply to prevent contamination. The District immediately responded to requests for emergency water supply in these areas. The Missouri National Guard began operating six water purification systems in St. Joseph, MO and was assisting in the distribution of potable water.

With National Weather Service predictions on 26 July that the Missouri River would rise to within three feet of the top of the North Kansas City levee, the local sponsor decided to evacuate the Downtown Municipal Airport as a precaution. The sponsor of the Central Industrial District levee considered temporarily raising the protective works but decided against it because of potential impacts to other levee projects in the area. The forecast called for a crest with 1-2 feet of freeboard remaining before overtopping. MRLS L-246, near Brunswick, MO overtopped along the Grand River. MRLS L-400 near Leavenworth, KS was overtopped. Sand boils on the Blue Rapids, KS levee at the upstream end of the Tuttle Creek Lake flood pool required remedial action, as did boils at the Northeast (East Bottoms) Levee at Kansas City.

On 27 July, the Chariton River tieback unit was overtopped. The decision was made to close all campgrounds and facilities at Truman Lake because of the high lake level.

On 28 July, Fort Leavenworth reported the loss of its water supply due to inundation of an electrical circuit to the pumps. Water levels along the Missouri River were receding somewhat upstream of Kansas City, but communities downstream in the vicinity of Jefferson City were experiencing record stages with the river expected to rise another two feet. At Kansas City, concerns were high. Levee patrols continued 24-hour operations, looking for potential problems and reading slope and river gages.

By 29 July, water quality at Truman Lake became a concern. There was danger that low dissolved oxygen in the lake and possible nitrogen supersaturation downstream would cause fish kills. At Glasgow, Missouri it was reported that a railroad abutment had failed and a portion of the railroad bridge was lying against the Missouri Highway 240 bridge.

Late on the evening of 30 July, the Monarch-Chesterfield Levee near St. Louis failed. This non-Federal levee unit protected 5,621 acres including the Spirit of St. Louis Airport, approximately 500 business, numerous residences, and U. S. Highways 40 and 61. By the end of July, four offices in the District, (the EOC, Public Affairs, Executive Office, and the Water Control Section) had processed more than 41,000 phone calls during the month. Other District offices also handled thousands of calls. Additional lines were installed in the EOC, but many callers still experienced a delay.

7. August-Week 1

The first of August saw the initial clean up work getting underway in west-northwest Missouri while the flood fight was reaching its zenith in the St. Louis area. On the 5th, 6th, and 7th of August rainfall amounts up to three-fourths of an inch were reported in various parts of the District in Missouri and Kansas. By the end of this week, the EOC had reduced operation from 24 hours to 12 hours per day.

8. August-Week 2

Damage assessment teams and technical support teams were dispatched to help local sponsors begin planning for rehabilitation. Three locations in the State of Missouri were set up to receive claims for assistance for levee repair under P. L. 84-99. Damage survey reports were begun in Kansas. Again, scattered precipitation fell on four days of the week. The heaviest was reported on 12 August with four to seven inches along the lower Missouri from Smithville to St. Louis. On the same date, up to two inches was reported over the northeast corner of Kansas.

9. August-Weeks 3 and 4

The District EOC formally ceased operations at noon on 20 August. The EOC facilities were immediately rearranged to establish the Rehabilitation Assistance Center (RAC). By 22 August, the Missouri River was completely open to navigation. By 29 August, all breached Federal levees had been inspected and the reports started. All known non-Federal levees in the Grand River basin had been inspected and teams were inspecting all non-Federal levees along the Missouri River. Initial repairs to MRLS R471- 460 and the North Kansas City Levee got underway. The Federal Emergency Management Agency was well along with the clean up of Elwood, KS. The Missouri and Kansas damage survey report activities continued.

10. September/Early October

Rehabilitation efforts got into full swing as many helpers from other parts of the nation arrived to assist District personnel. As of 19 September, there were 232 requests for levee rehabilitation. But the rain was not finished. On the first of September, there was general rainfall up to three-fourths of an inch in the District with heavier amounts in eastcentral Kansas and southcentral Missouri. Then on 14 September, heavy rains were reported in eastcentral Kansas, southern Iowa, and most of Missouri. The amounts ranged to more than 5 inches. By 19 September, the lower Missouri River from Hermann to the mouth was again above flood stage. Moderate to heavy rain of up to 2.8 inches continued in the Solomon, Republican, Smoky Hill, lower Big Blue and lower Platte River basins in north Kansas, southern Nebraska, and northern Missouri. For the next several days a storm moved from eastcentral Kansas across the State of Missouri with moderate rainfall of 2 to 3 inches or more in spots. The areas to the west and northwest of the City of Chesterfield in the St. Louis vicinity were inundated with 10 plus inches of rain. The initial repair contract for the Monarch-Chesterfield levee was modified to assist the local sponsor in building emergency embankments around a large breach at the upstream end of the project. The flood fight was successful with the temporary repairs holding back approximately seven feet of water in places. On 26 September, moderate to heavy rain fell over the District with the greatest amounts being 15.3 inches at Pittsburgh, KS and 7.3 inches at Lamar, MO. The middle one-third of Missouri received precipitation amounts between one and three inches. As a result of the constant rain, two lakes, Wilson and Pomme de Terre, were placed under critical surveillance and four lakes, Truman, Rathbun, Hillsdale, and Smithville were under increased surveillance. By 8 October, the Missouri River was below flood stage, bringing an end to the floods of 1993. The clean up continued.

## D. Areal Extent of Flooding

The 1993 Flood was unprecedented in the District in the number of acres flooded, the dollar amount of damages, the stages recorded along the Missouri River, the maximum pool elevations reached at lake projects, and the amount of damages prevented by Corps projects. Within the District, 3,707,000 acres were flooded. Plate 3 shows the counties in NE, IA, KS, and MO that were declared disaster areas by the President. Plates 4 through 6 are index sheets for the Missouri River flooded area plates. Plates 7 through 63 are maps showing the flooded areas along the Missouri and Kansas Rivers in the District. The approximate location of levee breaks is shown in red on the flooded area maps.

## III. Meteorology

### A. Antecedent Conditions

Precipitation during the winter of 1992-1993 and spring of 1993 was above average and temperatures were below average throughout the lower Missouri River basin. Snowfall accumulation for January was: 16-17 inches in Nebraska, 11 inches in central Missouri, and over 16 inches in north central Kansas. Persistent rains and early snowmelt culminated in high spring runoff. With the exception of some areas in Colorado and western Kansas, which had below average precipitation, April and May were wet and cool.

A wet-weather pattern persisted over the upper midwest for about six months. This pattern resulted from an eastward-flowing jetstream that extended from central Colorado northeastward across Kansas to northern Wisconsin. Because of this jetstream, a weather-front convergence zone formed across the upper midwest during the spring and summer months that preceded the flood. Moist, warm air from the Gulf of Mexico was drawn northward along this jetstream where it collided with cooler air masses drawn out of central Canada. The resultant unstable air masses persisted throughout the flooded area during the spring and summer of 1993.

Areal distribution of total precipitation for the six month period from January through July, 1993, is shown on Plate 64 in inches and on Plate 65 in terms of percentage of the normal 30-year precipitation (January through July, 1961-90). These plates were prepared by the National Weather Service. In the lower Missouri River basin, over 40 inches of precipitation (about 200 percent of average) occurred over about a 5,000 square mile area on the Kansas River upstream from Topeka, Kansas. It is also noteworthy that over 30 inches of precipitation (150 percent of average or greater) occurred over the lower Missouri River basin downstream from the Corps lakes, Wilson and Kanopolis, in central Kansas.

### B. Description of Storms

A description of the dominant weather pattern over the upper midwest in June and July is provided in following two excerpts from U.S. Geological Survey Circular 1120-B:

> In early June, a weather pattern (Plate 66) developed that was characterized by a strong low-pressure system over the western United States and a corresponding large high-pressure system positioned over the southeastern United States. The jetstream dipped south over the western United States and flowed northeasterly across the upper midwest. A southeastern high blocked the eastward movement of storms, thus creating a convergence zone between the warm, moist flow from the Gulf of Mexico

and the much cooler and drier air from Canada, which resulted in thunderstorms. This pattern persisted through most of June and July.

As a result, the upper midwest within this convergent zone was deluged with rain while the southeastern and eastern United States from Alabama to Vermont, under the influence of the high-pressure system, was very hot and dry. Slight movements in the atmospheric pattern determined the timing and location of excessive rainfall throughout the upper midwest. The persistence of this weather pattern caused unusually large amounts of moisture and the wetter-than-normal spring produced flooding throughout the upper Mississippi River basin, including the lower Missouri River basin.

Total monthly precipitation isohyetal maps prepared by the Climate Analysis Center, NOAA, for the months of May, June, and July are shown on Plates 67, 68 and 69. A review of these maps indicate that over the Missouri River basin downstream from westcentral Kansas, 4 to 12 inches of rain fell in May, 4 to 8 inches fell in June, and 4 to 16 inches fell in July.

**C. Rainfall Data for July 1993**

The magnitude and timing of intense thunderstorms in early and mid-July, coupled with wet antecedent conditions, were the principal causes of major and severe flooding on the Missouri River from Rulo, NE, to St. Louis, MO, and on most Missouri River tributaries. Precipitation in June was 150 to 200 percent of average throughout the basin with the exception of eastern Colorado. From 1-26 July, thunderstorms occurred on a regular basis, once or twice a week. There was very little or no rainfall during the period of 27-31 July. Rainfall totals in July were at or near record levels in every state except Colorado, which had the second driest July of record. Iowa experienced the wettest July of record; Kansas the second wettest July; and Missouri and Nebraska their third wettest July. Total precipitation isohyetal maps for July for each state (Iowa, Missouri, Kansas, and Nebraska) are shown on Plates 70, 71, 72 and 73.

The distribution of the 1-26 July, 1993, precipitation is portrayed by the mass rainfall curves on Plates 74 through 80 for 49 selected precipitation stations. The total rainfall at these stations varied from 14.7 inches at Shawnee, KS, up to 25.6 inches at Maryville, MO, and the total rainfall was over 20 inches at 21 of the precipitation stations. The approximate location of the precipitation station for each mass rainfall curve and other pertinent precipitation stations is listed by river basin and nearest lake project in Table 3. The areal distribution of the 1-26 July precipitation over the lower Missouri River basin is illustrated by the isohyetal map on Plate 81.

The isohyetal map and mass rainfall curves are based on daily and hourly precipitation data from monthly reports entitled "Climatological Data" and "Hourly Precipitation Data", which are published for each state by the National Oceanic

Atmospheric Administration (NOAA). The observation time for measuring rainfall on a daily basis is shown on each mass rainfall curve for the non-recording precipitation stations. An observation time of midnight is shown for the hourly recording precipitation stations. These mass rainfall curves reflect the accumulations of many small-to-moderate-to-large amounts of rainfall and show the effects of widespread storms occurring somewhere within the lower Missouri River basin on nearly a daily basis.

A review of the 1-26 July mass rainfall curves helps define distinct periods of large amounts of rainfall in certain areas of the basin. As shown by curves on Plate 78, the largest amount of rainfall in southcentral Iowa occurred during the period of 3-7 July with amounts ranging from 5.5 inches at Clio, up to 8.3 inches at Columbia. Plates 79 and 80 show large amounts of rainfall also occurred in Missouri during the period of 3-7 July with amounts at 7 stations ranging from 4.8 inches at Bethany, up to 8.6 inches at Conception.

In Kansas, the most intense storms occurred over a period of time from 3 to 10 July. As shown by Plates 76 and 77, rainfall amounts at 12 of the 14 stations exceeded 7 inches. The maximum rainfall amounts recorded during the 3-10 July period were 11.1 inches at Cawker City, 10.8 inches at Blaine, and 9.5 inches at Washington.

The most intense storm in the lower Missouri River basin occurred on 21-25 July. This storm was centered over the Missouri River tributary basins, upstream of St. Joseph, in southeast Nebraska, northwest Missouri and southwest Iowa. There were unofficial reports of as much as 16 inches of rainfall in southeast Nebraska. An isohyetal map of the 21-25 July storm period is presented on Plate 82. The greatest amounts of rainfall recorded were 12.5 inches at Weeping Water, 12.0 inches at Nebraska City, and 10.1 inches at Syracuse in Nebraska, and 11.6 inches at Hamburg in Iowa. As indicated on Plates 74 and 75, rainfall amounts varied from 6.1 inches up to 8.5 inches at the other 7 stations located above St. Joseph. Plate 79 shows rainfall amounts in northcentral Missouri varied from 6.1 inches up to 9.0 inches at Maryville and 10.1 inches at Pattonsburg. Plate 78 shows rainfall amounts varied from 4.8 up to 7.4 inches at 5 stations in southcentral Iowa.

## Table 3
## Total Precipitation for Period of 1-26 July, 1993

| Precipitation Station | Total Rainfall (Inches) | River Basin | Nearest Lake Project |
|---|---|---|---|
| Republican and Smoky Hill Rivers | | | |
| Harlan Co Lake, NE | 13.3 | Republican | Harlan County |
| Franklin, NE | 13.9 | Republican | Harlan County |
| Concordia, KS | 16.8 | Republican | Milford |
| Scandia, KS | 19.2 | Republican | Milford |
| Alton, KS | 18.5 | Solomon | Waconda |
| Beloit, KS | 19 | Solomon | Waconda |
| Cawker City, KS | 20.3 | Solomon | Waconda |
| Ionia, KS | 16.5 | Solomon | Waconda |
| Tescott, KS | 19.6 | Saline | Kanopolis |
| Wilson Lake, KS | 11.3 | Saline | Wilson |
| Kanopolis Lake, KS | 11.4 | Smoky Hill | Kanopolis |
| Salina, KS | 17.9 | Smoky Hill | Kanopolis |
| Kansas River Tributaries | | | |
| Axtell, KS | 22 | Big Blue | Tuttle Creek |
| Blaine, KS | 23.2 | Big Blue | Tuttle Creek |
| Blue Rapids, KS | 19.6 | Big Blue | Tuttle Creek |
| Centralia, KS | 19.7 | Big Blue | Tuttle Creek |
| Marysville, KS | 23.4 | Big Blue | Tuttle Creek |
| Washington, KS | 19.6 | Little Blue | Tuttle Creek |
| Onaga, KS | 13.8 | Kansas | Tuttle Creek |
| Perry Lake, KS | 16.2 | Delaware | Perry |
| Horton, KS | 21.8 | Delaware | Perry |
| Osage River Basin | | | |
| Melvern Lake, KS | 14.1 | Marais des Cygnes | Melvern |
| Osage City, KS | 16.1 | Marais des Cygnes | Pomona |
| Garnett, KS | 16.5 | Marais des Cygnes | Melvern |
| Clinton, MO | 18.2 | South Grand | Harry S. Truman |
| Drexel, MO | 15.7 | South Grand | Harry S. Truman |
| Kingsville, MO | 16.5 | South Grand | Harry S. Truman |
| Appleton City, Mo | 13.4 | Osage | Harry S. Truman |
| Platte and Grand Rivers | | | |
| Bethany, MO | 22.6 | Grand | None |
| Conception, MO | 24.4 | Platte | None |
| King City, MO | 20.7 | Platte | Smithville |
| Milan, MO | 20.1 | Locust Creek | None |
| Pattonsburg, MO | 21.1 | Grand | None |
| Spickard, MO | 21.1 | Thompson | None |

**Table 3**
**Total Precipitation for Period of 1-26 July, 1993**

| Precipitation Station | Total Rainfall (Inches) | River Basin | Nearest Lake Project |
|---|---|---|---|
| Blockton, IA | 19.4 | Platte | None |
| Beaconsfield, IA | 19.7 | Thompson | None |
| Clio, IA | 20.5 | Medicine Creek | Rathbun |
| Leon, IA | 20.7 | Thompson | None |
| Mount Ayr, IA | 19 | Grand | None |
| Missouri River Tributaries above St. Joseph | | | |
| Auburn, NE | 19.6 | Little Nemaha | None |
| Nebraska City, NE | 22.7 | Missouri | None |
| Syracuse, NE | 18.6 | Little Nemaha | None |
| Weeping Water, NE | 19 | Weeping Water | None |
| Hamburg, IA | 20 | Nishnabotna | None |
| Fairfax, MO | 23.2 | Tarkio | None |
| Tarkio, MO | 18.9 | Tarkio | None |
| Troy, KS | 17 | nr. Wolf Creek | None |
| Graham, MO | 23.2 | Nodaway | None |
| Maryville, MO | 25.6 | Nodaway | None |
| Oregon, MO | 20.6 | nr. Nodaway | None |
| Dubois, NE | 16.2 | S Fk Nemaha | Tuttle Creek |
| Falls City, NE | 24.6 | Nemaha | Tuttle Creek |
| Pawnee City, NE | 24.2 | S Fk Nemaha | None |
| Table Rock, NE | 24.4 | N Fk Nemaha | None |
| Chariton and Little Chariton Rivers | | | |
| Chariton, IA | 17.5 | Chariton | Rathbun |
| Columbia, IA | 18.3 | nr. Chariton | Rathbun |
| Derby, IA | 15.6 | Chariton | Rathbun |
| Kirksville, MO | 14.7 | Little Chariton | Long Branch |
| Missouri River Tributaries below Kansas City | | | |
| Shawnee, KS | 14.7 | Blue River | Longview |
| Stanley, KS | 15 | Blue River | Longview |
| Unity Village, MO | 10.6 | Little Blue | Blue Springs |
| Warrensburg, MO | 11.6 | Lamine | Harry S. Truman |
| Highpoint, MO | 13.4 | Moreau | Lake of Ozarks |

## D. Comparison With Historic Storms

The National Weather Service (1993) computed statewide-average precipitation by month from 1895 to the present for the U.S. Geological Survey (USGS) and the results are presented in USGS Circular 1120-B. Statewide averages for July 1993 were among the three wettest years since 1895 for eight of the nine States in the flood-affected area for the upper Mississippi River Basin. Precipitation totals for the 3-month period of May through July were computed at Manhattan, Kansas, for the 104 years of record. Comparing period-of-record maximums for the 3-month period, the 1993 May-through-July precipitation total of 35.4 inches (11.0" May, 6.8" June, 17.6" July) was the second wettest such period in 104 years of record. The wettest 3-month precipitation total of 36.7 inches occurred in 1951. The 3-month totals for the 3rd, 4th and 5th wettest periods were 28.2 inches in 1915, 25.2 inches in 1908, and 22.7 inches in 1977. The 1993 rainfall total at Manhattan resulted primarily from three distinct storm periods: 7-11 May , 1-2 July, and 18-22 July, and the maximum 5-day rainfall total was 7.7 inches.

The storm of July 1951 produced the flood of record on the Kansas River and major flooding on the downstream Missouri River. A constant movement of warm air from the Gulf of Mexico which met cool air from the north led to widespread storms at frequent intervals. Following a two-month period of above-normal precipitation, large amounts of rainfall occurred over the Osage-Marais des Cygnes River and Kansas River basins during a 5-day storm period of 9-13 July. In May, rainfall over Kansas averaged 6.4 inches. The average rainfall of 9.6 inches over Kansas in June was the greatest monthly average rainfall of record at that time. Light rains the first part of July kept the soils well saturated. Precipitation during the period of 9-13 July amounted to as much as 18.5 inches in certain areas. The areal distribution was 15.5 inches over 1,000 square miles, 13.1 inches over 5,000 square miles, 11.5 inches over 10,000 square miles, and 9.5 inches over 20,000 square miles.

The storm of May 1935, characterized by intense precipitation over the Republican River, is of interest because of its relatively high intensity over a small area. A maximum rainfall of 24 inches in a period of 6 hours was reported. For small areas and short durations, storm precipitation in 1935 exceeds that of the 1951 storm. For an area of 2,000 square miles and duration of 24 hours, the maximum average rainfall in May 1935 was 5.5 inches, as compared to 6.2 inches for the July 1951 storm.

The storm of 6-11 May 1943 is of particular interest by virtue of the heavy precipitation that occurred over a large area. Rainfall from this storm extended from Oklahoma and Arkansas northeastward across southeastern Kansas and into Missouri, Illinois and Indiana. A total of over 200,000 square miles is encompassed by the 3-inch isohyet for the 1943 storm compared to 57,000 square miles for the July 1951 storm. In 1952, it was determined the average depth of rainfall of the May 1943 storm exceeded all other storms for durations in excess of 24 hours. The storm center was at Warner, Oklahoma, where 25 inches of precipitation were reported for the storm period of 192 hours. For a 72-hour duration this storm had approximately 15 percent greater rainfall depth than the July 1951 storm.

## IV. Hydrology

### A. Description of Flooding

Hydrologic and hydraulic effects of excessive runoffs during the summer of 1993 resulted in severe and widespread flooding throughout the lower Missouri River basin in Missouri, central and east Kansas, southeast Nebraska and southcentral and southwest Iowa. Several intense storms in July, combined with wet antecedent conditions, were the principal causes of the severe flooding conditions. Record flooding inundated large residential, industrial and agricultural areas. The extent and duration of flooding caused levees on the Missouri River to fail or be overtopped. Damaged bridges and submerged highways and roads disrupted overland transportation and the Missouri River was closed to navigation for 49 days, from 2 July to 20 August. Large areas of agriculture lands were inundated and some of the areas remained under water for weeks during the growing season. Also, the banks and channels of some of the rivers (streams) were severely eroded.

The stage hydrographs on Plates 83 through 93 depict flooding conditions that occurred at pertinent locations on the Kansas, Missouri and Grand Rivers during the period of 1 May through 30 October 1993. The following paragraphs provide a description of flooding conditions by river reach for the Missouri River, and a general description of flooding conditions on the Kansas and Grand Rivers.

1. Missouri River - Rulo to Kansas City

Plates 83 through 87 show stage hydrographs for five Missouri River stations. The Missouri River at St. Joseph was at or above flood stage (17.0 feet) from 26 June to 6 August for a total of 43 days. The river crested on 26 July at a stage of 32 feet (15 feet above flood stage). At Kansas City, the Missouri River was at or exceeded flood stage (32.0 feet) from 3 July to 6 August for a total of 36 days. The river crested on 27 July at a stage of 49.0 feet (17 feet above flood stage). A comparison of the stage hydrographs at these two stream gaging stations shows that the time required for the 1993 flood crest to travel from St. Joseph to Kansas City was about one day, over a distance of 82 river miles.

2. Kansas River

Stage hydrographs are shown on Plates 88 through 92 for five selected stream gaging stations on the Kansas River. In early May, the river was above flood stage at the Topeka and Lecompton stations for four days from 10 May through 13 May, which resulted from heavy rainfall over the basin on 9-10 May. The next significant flooding began on 19 July when river stages rose rapidly, due to heavy rainfall on 18-19 July, and stages exceeded flood stage at the Fort Riley, Wamego, Topeka and Lecompton stations. Persistent rainfall over the basin until 24 July contributed to flooding conditions which lasted until 4-7 August. The duration of flooding varied from 17 to 19 days at these four gaging stations. The lower gaging station at Desoto near Kansas City was above flood stage for seven days from 25 July to 31 July.

3. Missouri River - Kansas City to Boonville

The Missouri River at Boonville was at or above flood stage (21.0 feet) from 1 July through 16 August for a total duration of 47 days. The river crested on 29 July at a stage of 37 feet (16 feet above flood stage). A comparison of the stage hydrographs indicates the travel time from Kansas City to Booneville was about 2 days, over a distance of 169 miles.

4. Grand River

The Grand River at Sumner was at or above flood stage (26.0 ft.) from 3 July through 7 August for a total of 36 days. The river crested on 10 July at a stage of 42.52 feet (16.52 feet above flood stage). Plate 93 is the stage hydrograph for the Grand River.

5. Missouri River - Boonville to Hermann

The Missouri River at Hermann was at or above flood stage (21.0 feet) from 2 July to 25 August for a total of 54 days. The river crested on 31 July at a stage of 37 feet (16 feet above flood stage). A comparison of the stage hydrographs indicates the travel time from Booneville to Hermann was one day, over a distance of 99 miles. The total time for the 1993 flood crest on the Missouri River flood to travel from Rulo to Hermann was about 4 days.

## B. Highwater Marks

Highwater marks for the 1993 Flood were established on the Missouri River and several tributary streams. A subsequent survey of the 112 highwater marks on the Missouri River was made and the highwater mark elevations are shown in following table and on the flooded area maps on Plates 7 through 50. The 1993 Flood highwater mark profile for the Missouri River is shown on Plates 94 through 98. Flooded area maps for the Kansas River are on Plates 51 through 63. The 1993 flood profile for the Grand, Thompson and Solomon Rivers are on Plates 99 through 107.

## Table 4
## 1993 Missouri River Highwater Marks

| River Mile | Bank | Elev. | River Mile | Bank | Elev. | River Mile | Bank | Elev. |
|---|---|---|---|---|---|---|---|---|
| 498.1 | R | 863.40 | 322.7 | R | 702.71 | 160.0 | R | 571.54 |
| 493.9 | L | 859.83 | 318.9 | R | 699.93 | 158.0 | R | 571.19 |
| 488.2 | R | 857.24 | 316.3 | L | 697.80 | 154.5 | L | 568.60 |
| 485.2 | R | 855.64 | 313.4 | L | 693.92 | 149.2 | L | 564.58 |
| 480.2 | R | 852.22 | 308.7 | L | 688.95 | 145.6 | R | 562.96 |
| 477.1 | L | 848.41 | 303.6 | L | 684.13 | 139.0 | R | 554.52 |
| 473.7 | R | 845.63 | 298.6 | L | 681.79 | 134.5 | R | 552.38 |
| 468.4 | R | 841.25 | 293.5 | R | 677.16 | 132.0 | R | 548.66 |
| 462.6 | L | 836.07 | 288.9 | L | 673.59 | 129.4 | R | 546.44 |
| 457.0 | R | 829.94 | 284.1 | R | 670.68 | 124.7 | L | 541.65 |
| 452.1 | L | 826.98 | 279.4 | R | 657.98 | 120.2 | L | 538.76 |
| 448.0 | L | 822.00 | 274.9 | L | 663.42 | 117.9 | R | 535.63 |
| 446.1 | L | 849.59 | 269.9 | L | 657.31 | 114.2 | L | 532.54 |
| 441.0 | L | 814.37 | 266.6 | R | 658.17 | 110.0 | L | 529.48 |
| 437.2 | L | 809.58 | 263.9 | R | 657.16 | 99.9 | R | 521.90 |
| 431.2 | R | 801.08 | 262.8 | R | 653.91 | 97.7 | R | 517.94 |
| 426.9 | L | 797.52 | 261.1 | L | 652.42 | 94.9 | L | 515.70 |
| 422.6 | R | 793.83 | 256.3 | L | 648.83 | 89.9 | L | 511.27 |
| 416.3 | L | 789.20 | 251.8 | R | 647.45 | 85.5 | L | 508.35 |
| 410.3 | L | 786.30 | 247.8 | L | 645.09 | 74.0 | L | 496.95 |
| 406.6 | R | 783.98 | 242.1 | R | 639.93 | 69.6 | R | 494.14 |
| 401.3 | L | 776.41 | 236.3 | R | 635.33 | 68.3 | R | 493.53 |
| 397.4 | R | 777.32 | 230.9 | R | 630.53 | 64.3 | R | 488.93 |
| 395.0 | L | 774.12 | 226.1 | L | 625.30 | 60.0 | L | 486.61 |

**Table 4**
**1993 Missouri River Highwater Marks**

| River Mile | Bank | Elev. | River Mile | Bank | Elev. | River Mile | Bank | Elev. |
|---|---|---|---|---|---|---|---|---|
| 389.6 | L | 772.46 | 220.8 | R | 622.55 | 56.0 | L | 482.53 |
| 384.0 | L | 767.59 | 214.2 | R | 610.33 | 50.8 | L | 477.95 |
| 379.9 | R | 766.20 | 209.8 | R | 612.66 | 48.6 | L | 475.50 |
| 377.3 | L | 753.88 | 205.0 | L | 609.16 | 44.7 | R | 472.01 |
| 373.6 | R | 762.84 | 200.5 | L | 605.46 | 40.1 | R | 466.73 |
| 370.5 | L | 761.20 | 196.3 | L | 602.14 | 29.8 | R | 456.99 |
| 360.4 | L | 746.24 | 195.1 | L | 601.31 | 24.8 | L | 449.48 |
| 358.1 | R | 742.01 | 190.2 | L | 596.12 | 20.0 | R | 445.35 |
| 352.6 | R | 736.20 | 186.0 | L | 594.36 | 15.9 | L | 442.27 |
| 345.3 | L | 729.91 | 185.1 | R | 590.98 | 10.4 | L | 440.06 |
| 339.4 | R | 722.88 | 178.8 | L | 587.90 | 5.1 | R | 437.90 |
| 336.2 | R | 718.26 | 174.8 | R | 582.99 | 0.6 | L | 437.57 |
| 331.6 | R | 710.23 | 169.6 | L | 579.43 | | | |
| 328.6 | R | 708.21 | 164.4 | R | 576.72 | | | |

## C. Comparison With Historic Floods

Extensive and record flooding occurred on the mainstem of the Missouri River and on the Kansas River and other tributary streams of the Missouri River. Record flood stages occurred at many stream gaging stations as reflected in Tables 5 and 6. Table 5 compares the 1993 peak stage and peak discharge with previous maximum peak discharge and corresponding stage at eight stream gaging stations located on Missouri River tributary streams. Most notable are the record peak stage and discharge that occurred on the two tributary streams near St. Joseph. The record peaks on 23 July and 25 July are the result of the 22-24 July storm that was centered over the Missouri River upstream from St. Joseph. Table 6 compares the 1993 peak stage and peak discharge with the two previous maximum stages and corresponding discharges at five stream gaging stations on the Kansas River and five stations on the Missouri River. On the Kansas River, the 1993 stages are the second highest stage of record at four stations and third highest stage at one station. On the Missouri River, the 1993 stages are the maximum of record for all five stations listed. The following subparagraphs provide additional information for the historic floods of record.

**Table 5**
**Missouri River Tributary Streams**
**Comparison of 1993 Peak Stages and Discharges**
**With Previous Maximum Peak Discharge**

| Streamflow Gage Station Name | Drainage Area (sq. mi.) | 1993 Flood Peak | | | Previous Flood Peak | | |
|---|---|---|---|---|---|---|---|
| | | Stage (ft.) | Date | Discharge (cfs) | Stage (ft.) | Date | Discharge (cfs) |
| Big Nemaha River nr Fall City, NE | 1,340 | 29.80 | 7/6/93 | 59,000 | 31.40 | 10/1973 | 71,600 |
| Nodaway River at Clarinda, IA | 762 | 22.95 | 7/22/93 | 28,000 | 25.30 | 6/1947 | 31,100 |
| Nodaway River nr Graham, MO | 1,380 | 26.14 | 7/23/93 | 70,000 | 23.34 | 9/1989 | 26,600 |
| Platte River nr Agency, MO | 1,760 | 36.07 | 7/25/93 | 60,800 | 35.05 | 7/1965 | 53,000 |
| Grand River nr Gallatin, MO | 2,250 | 41.5 | 7/07/93 | 89,800 | 39.55 | 6/1947 | 69,100 |
| Grand River nr Sumner, MO | 6,880 | 42.52 | 7/10/93 | 166,600 | 39.50 | 6/1947 | 180,000 |
| Chariton River at Novinger, MO | 1,370 | 25.71 | 7/24/93 | 21,500 | 28.50 | 6/1947 | 22,900 |
| Chariton River nr Prairie Hill, MO | 1,870 | 21.93 | 7/01/93 | 31,500 | 21.96 | 4/1973 | 31,900 |

## Table 6
## Kansas and Missouri Rivers
## Top Three Floods of Record in Stage *

| Stream Gage | | | Flood No. 1 | | | Flood No. 2 | | | Flood No. 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Place | River Mile | Flood Stage (ft.) | Date | Dis-charge (cfs) | Stage (ft.) | Date | Dis-charge (cfs) | Stage (ft.) | Date | Dis-charge (cfs) | Stage (ft.) |
| Kansas River | | | | | | | | | | | |
| Fort Riley | 168.9 | 21.0 | 7/12/51 | 298,000 | 30.53 | 7/26/93 | 87,600 | 27.93 | 10/13/73 | 59,400 | 23.7 |
| Wamego | 126.9 | 19.0 | 7/13/51 | 400,000 | 30.56 | 7/26/93 | 199,000 | 27.33 | 6/04/35 | 177,000 | 26.8 |
| Topeka | 83.1 | 26.0 | 7/13/51 | 469,000 | 40.80 | 7/25/93 | 170,000 | 34.90 | 10/12/73 | 130,000 | 27.3 |
| Lecompton | 63.8 | 17.0 | 7/13/51 | 483,000 | 30.23 | 7/27/93 | 190,000 | 24.65 | 10/12/73 | 140,000 | 22.7 |
| Desoto | 31.0 | 24.0 | 7/13/51 | 510,000 | 37.30 | 10/13/73 | 146,000 | 27.50 | 7/27/93 | 170,000 | 26.9 |
| Missouri River | | | | | | | | | | | |
| St. Joseph | 448.2 | 17.0 | 7/26/93 | 335,000 | 32.07 | 4/22/52 | 397,000 | 26.82 | 6/16/84 | 198,000 | 25.9 |
| Kansas City | 366.1 | 32.0 | 7/27/93 | 541,000 | 48.87 | 7/14/51 | 573,000 | 46.20 | 4/24/52 | 400,000 | 40.6 |
| Waverly | 233.4 | 20.0 | 7/27/93 | 633,000 | 31.15 | 6/23/84 | 245,000 | 29.22 | 10/13/73 | 262,000 | 28.9 |
| Boonville | 197.1 | 21.0 | 7/29/93 | 755,000 | 37.10 | 7/17/51 | 550,000 | 32.82 | 10/5/86 | 334,000 | 31.9 |
| Hermann | 97.9 | 21.0 | 7/31/93 | 750,000 | 36.97 | 10/5/86 | 549,000 | 35.79 | 4/25/73 | 500,000 | 33.7 |

* Table does not include flood data prior to 1930 because few stream gage stations were operating at that time.

1. Flood of June 1844

The Flood of 1844 is the greatest historic flood in the lower Missouri River basin. Records of stages at Kansas City and St. Louis, Missouri, are authentic. Reliable high water marks have been established at Boonville and Hermann on the Missouri River and at Manhattan and Topeka on the Kansas River. In Kansas, total rainfalls for May and June were 20.08 inches at Ft. Leavenworth and 27.43 inches at Ft. Scott. Stream gage data for the Flood of 1844 are not available for inclusion in Table 6.

2. Floods of 1915

In terms of total recorded rainfall the year 1915 was one of the wettest years of record and the lower Missouri River basin streams were at or above flood stage for several weeks, but extremely high stages were not observed. Stream gage data are not available for inclusion in Table 6.

3. Flood of July 1951

The following two excerpts from the interim report entitled "Storms and Floods, May-July 1951" best describe this flood:

> The July 1951 storm was the greatest of record in the lower Kansas and upper Osage River basins, with the possible exception of the historical June 1844 storm for which there are virtually no precipitation records.
>
> The storm of 9-13 July 1951 greatly exceeded that of May 1903, particularly for a duration of 72 hours for which period it produced 60 to 70 percent more rainfall. For some areas the duration of the July 1951 storm is the greatest storm of record in the entire region north of the latitude through the Kansas-Oklahoma border and between the Rocky Mountains and the Appalachians.

The crest on the Missouri River at Kansas City was 1.8 feet below the maximum stage of the June 1844 flood. The Kansas River crest exceeded maximum stages recorded prior to 1951 at all locations.

4. Flood of April 1973

March 1973 was an unusually wet month. During the first week of April above average rainfall continued. Amounts of 8 to 10 inches were common in central Missouri. Flood stages on the lower Missouri River reached the magnitude of the 1951 flood stages, with the flood at Hermann cresting 0.4 foot above the 1951 crest and the flood near St. Louis cresting 0.9 foot below the 1951 crest.

5. Flood of October 1973

The Flood of October 1973 was the result of a storm centered in northcentral and northeastern Kansas and southcentral and southeastern Nebraska. Prior to the Flood of 1993, the Flood of October 1973 resulted in the highest stages on the Kansas River since the reservoirs in the Kansas River basin were placed in operation and caused record high reservoir levels at Tuttle Creek, Milford, and Perry Lakes in Kansas. The Flood of October 1973 also resulted in high stages on the Missouri River, including the third highest stage on record at Waverly, Missouri.

**D. Project (Lake and Reservoir) Effects on Downstream Flooding**

1. Kansas River

The operation of the 18 District and Bureau lake and reservoir projects in the Kansas River basin for flood control purposes resulted in significant reductions in the depth of flooding that occurred in July-August 1993 on the Kansas River, Missouri River, and those tributary streams of the Kansas River below each project. Table 7 contains information on stage reductions at five pertinent locations on the Kansas River. Reduction in stage varies from 1.6 feet at Wamego to 7.1 feet at Fort Riley. In the lower reach at Desoto, Kansas, near the Kansas City metropolitan area, the flooding depth was reduced 4.5 feet.

**Table 7**
**Kansas River - 1993 Flood**
**Actual and Unregulated Stages & Discharges**

| Stream Gage | | | Actual | | | Unregulated | | Stage Reduction by Federal Reservoirs (ft.) |
|---|---|---|---|---|---|---|---|---|
| Place | River Mile | Flood Stage (ft.) | Date | Discharge (cfs) | Stage (ft.) | Discharge (cfs) | Stage (ft.) | |
| Fort Riley | 168.9 | 21.0 | 7/26/93 | 87,600 | 27.9 | 200,000 | 35.0 | 7.1 |
| Wamego | 126.9 | 19.0 | 7/26/93 | 199,000 | 27.3 | 258,000 | 28.9 | 1.6 |
| Topeka | 83.1 | 26.0 | 7/25/93 | 170,000 | 34.9 | 260,000 | 37.1 | 2.2 |
| Lecompton | 63.8 | 17.0 | 7/27/93 | 190,000 | 24.7 | 282,000 | 26.9 | 2.3 |
| Desoto | 31.0 | 24.0 | 7/27/93 | 170,000 | 26.9 | 266,000 | 31.4 | 4.5 |

2. Missouri River

Table 8 presents information on stage reductions at five pertinent locations on the lower Missouri River below Rulo, Nebraska. These stage reductions reflect the flood control operational effects of the previously mentioned projects in the Kansas River basin; the other 11 District lake projects in the lower Missouri River basin [Metro Kansas City area (3), Chariton River and Little Chariton River basin (2), and Osage River basin (6)]; as well as the Missouri River mainstem and tributary reservoir system upstream of Rulo. Reduction in stage varied from 2.9 feet at Hermann to 3.3 feet at Boonville. The 1.8 foot stage reduction at St. Joseph was due entirely to the reservoir system upstream of Rulo. The six projects in the Osage River basin were operated to reduce flood stages at Hermann and also to lower stages on the Mississippi River at St. Louis.

## Table 8
## Missouri River - 1993 Flood
## Actual and Unregulated Stages & Discharges

| Stream Gage | | | Actual | | | Unregulated | | Stage Reduction by Federal Reservoirs (ft.) |
|---|---|---|---|---|---|---|---|---|
| Place | River Mile | Flood Stage (ft.) | Date | Discharge (cfs) | Stage (ft.) | Discharge (cfs) | Stage (ft.) | |
| St. Joseph | 448.2 | 17.0 | 7/26/93 | 335,000 | 32.1 | 461,000 | 33.9 | 1.8 |
| Kansas City | 366.1 | 32.0 | 7/27/93 | 541,000 | 48.9 | 713,000 | 52.2 | 3.3 |
| Waverly | 233.4 | 20.0 | 7/27/93 | 633,000 | 31.2 | 700,000 | 34.4 | 3.2 |
| Boonville | 197.1 | 21.0 | 7/29/93 | 755,000 | 37.1 | 820,000 | 40.4 | 3.3 |
| Hermann | 97.9 | 21.0 | 7/31/93 | 750,000 | 37.0 | 852,000 | 39.9 | 2.9 |

### 3. Damage Prevented

Damages prevented by lake and reservoir projects are presented in Section X and specific information on streamflow regulation at each project is discussed in Section V.

## E. Flow Frequency

A discharge-frequency study for the Missouri River was made by the Corps of Engineers in 1962. The 100-year and 500-year peak discharge estimates for stream gaging stations on the Missouri River are shown in the first two columns of Table 9. These estimates reflect the operation of the existing Missouri River system of lakes and reservoirs. For comparison purposes, the peak discharges for the 1993 flood are shown in the third column of this table. Based on this information, one might conclude the frequency of the 1993 flood is approximately a 500-year event. However, in order to make a reasonably reliable estimate of the frequency of the 1993 flood, an updated analysis of the 1962 study would be required. A reanalysis would need to include the 1993 peak discharges and all other annual peak discharges that have occurred since the study was made. A thorough and complete discharge-frequency reevaluation for the Missouri River is beyond the scope of this report.

A comparison of the 1993 unregulated (no lakes or reservoirs) peak discharges with the 1844 estimated peak discharges is presented in the fourth and fifth columns of Table 9. The 1844 peak discharge at Hermann is greater than the 1993 unregulated peak discharge and the 1993 unregulated peak discharges at Kansas City and Boonville are greater than the 1844 peak discharges.

**Table 9**
**Data on Frequency of Peak Discharges on the Missouri River**

| Stream Gage Station | 1962 Study | | 1993 Flood | | 1844 Flood |
|---|---|---|---|---|---|
| | 100-Year Peak Discharge (cfs) | 500-Year Peak Discharge (cfs) | Actual Peak Discharge | Unregulated Peak Discharge | Estimated Peak Discharge (cfs) |
| St Joseph | 270,000 | 330,000 | 335,000 | 461,000 | |
| Kansas City | 425,000 | 540,000 | 541,000 | 713,000 | 625,000 |
| Waverly | 445,000 | 560,000 | 633,000 | 700,000 | |
| Boonville | 550,000 | 700,000 | 755,000 | 820,000 | 710,000 |
| Hermann | 620,000 | 820,000 | 750,000 | 852,000 | 892,000 |

## F. Impacts on Missouri River Bank Stabilization and Navigation Project

1. Channel Changes and River Structure Damage

Post 1993 flood aerial photography indicates severe damages were sustained in the floodplains and considerable damages were also inflicted on the bank stabilization and navigation structures. Although numerous bankline blowouts occurred, some of which initiated channel cut-offs, the primary rectified main stem channel remained intact. A review of this post flood photography reveals several consistent corollaries concerning the damage imposed on the rectified channel's structures. These are:

a. Most of the damages inflicted on the channel structures were due to the failure of private levees which were constructed close to the edge of the bankline.

b. The channel structure damages usually occurred where private levees failed at places where they crossed old meanders or oxbows.

c. Most of these private levee failures occurred at or near the upstream end of the levee, (tie off), which indicates that insufficient height is provided against flank exposure.

Table 10 lists the locations of initiated channel changes and c[illegible] development during the 1993 Flood. The exit and re-entry locations are indicat[illegible] river mile.

**Table 10**
**Channel Changes and Chute Development**
**1993 Missouri River Flood**

| River Mile | | Chute Length River Miles | Bank Line | |
|---|---|---|---|---|
| Exit | Re-Entry | | Right | Left |
| 412.5 | 410.0 | 2.5 | | X |
| 393.8 | 388.0 | 5.8 | X | X |
| 351.8 | 345.6 | 6.2 | | X |
| 332.8 | 289.0 | 43.8 | | X |
| 258.1 | 246.5 | 11.8 | X | |
| 253.8 | 250.0 | 3.8 | | X |
| 231.4 | 217.8 | 13.6 | X | |
| 211.5 | 204.0 | 7.5 | | X |
| 196.0 | 177.3 | 18.7 | | X |
| 172.2 | 166.8 | 5.4 | | X |
| 92.5 | 82.5 | 10.0 | X | |
| 82.0 | 73.2 | 8.8 | | X |
| 38.0 | 33.5 | 4.5 | | X |
| 23.0 | 3.0 | 20.0 | | X |

Table 11 shows a list of the major and significant blow-outs, different than those referenced for the channel or chute development. These are shown by bank locations and current river mileage. In this table, the classification of major is for those channel banklines where the length of the blowout was 1,000 to 2,000 feet or more. Classification of significant is for those areas where length of blowout was several hundred feet. Some of these blowouts, as well as numerous other less significant breeches, were continuous contributors toward the development of near channel change or chute development by supplying lateral incremental discharges.

Most of the channel changes or chutes across the floodplains were developed by flows being trained by remaining portions of interior levees, terraces, and/or roadways. Discharge through the channel change or chute was continually being reinforced from lateral breeches in private levees. In several instances the "Domino effect" greatly extended the chute development by breaching tributary tie-back levees and, in the narrows, downstream of Glasgow, MO by breaching the main stem private levees. It should be noted from the above tables that very little of the river's structural damage was incurred from Rulo, Nebraska to above Kansas City, Missouri. Primarily, a large number of Federal levees exist in this reach and were constructed along a corridor designed to pass flood magnitudes in the range experienced during the 1993 Flood. Photographs 1 and 2 show typical blowouts.

**Table 11**
**Blowouts 1993 Flood**
**Missouri River Bank Stabilization and Navigation Structures**

| Missouri River Mile | Right Bank | | Left Bank | |
|---|---|---|---|---|
| | Major | Significant | Major | Significant |
| Reach 1. Rulo, Nebraska RM 498.1 to Leavenworth, Kansas RM 396.7 | | | | |
| 486.8 | | X | | |
| 480.8 | | | | X |
| 477.9 | | | | X |
| 476.7 | | X | | |
| 465.2 | | | | X |
| 462.2 | | | | X |
| 456.0 | | X | | |
| 441.9 | | X | | |
| 440.0 | | X | | |
| 438.4 | | X | | |
| 434.5 | | X | | |
| 428.8 | | X | | |
| 426.8 | | | X | |
| 417.4 | | | | X |
| 416.7 | | | | X |
| Reach 2. Leavenworth, Kansas to Kansas City, Missouri RM 366.1 | | | | |
| 386.0 | X | | | |
| Reach 3. Kansas City, Missouri to Miami, Missouri RM 262.6 | | | | |
| 356.2 | | | | X |
| 355.8 | | | | X |
| 340.5 - 342 | | | X | |
| 326 - 325 | | | X | |

# Table 11
## Blowouts 1993 Flood
## Missouri River Bank Stabilization and Navigation Structures

| Missouri River Mile | Right Bank | | Left Bank | |
|---|---|---|---|---|
| | Major | Significant | Major | Significant |
| 315.5 | | | | X |
| 311.1 | | | | X |
| 300.2 | | X | | |
| 299 | | X | | |
| 280 | | X | | |
| 273.1 | | X | | |
| 267.7 | | | | X |
| 264 | | X | | |
| 267.6 | | | | X |
| 263 - 264 | | | | X |
| Reach 4. Miami, Missouri to Glasgow, Missouri RM 226.3 | | | | |
| 261.5 | X | | | |
| 250.5 | | X | | |
| 250.0 | | X | | |
| 237.5 | | X | | |
| 235.3 | | X | | |
| 240.7 | X | | | |
| 240.3 | X | | | |
| 238.0 | | | | X |
| Reach 5. Glasgow, Missouri to Boonville, Missouri RM 197.1 | | | | |
| 218.3 - 217.5 | | | X | |
| 214.8 | | X | | |
| 214.5 | | | | X |
| 214.0 | | | | X |
| 211.5 | | | | X |
| 211.0 | | | | X |
| Reach 6. Boonville, Missouri to Hermann, Missouri RM 97.1 | | | | |
| 195.5 | | X | | |

# Table 11
# Blowouts 1993 Flood
# Missouri River Bank Stabilization and Navigation Structures

| Missouri River Mile | Right Bank | | Left Bank | |
|---|---|---|---|---|
| | Major | Significant | Major | Significant |
| 188.8 | | X | | |
| 179.3 | | X | | |
| 171.0 | | X | | |
| 167.2 | | | | X |
| 163.8 | | X | | |
| 162.8 | | X | | |
| 162.5 | | | | X |
| 159.8 | | | | X |
| 159.5 | | | | X |
| 159.3 | | | | X |
| 153.5 | | X | | |
| 150.4 | | X | | |
| 142.5 | | | X | |
| 117.7 | | | | X |
| 108.5 | | | X | |
| 106.8 | | | X | |
| 102.0 | | | | X |
| Reach 7. Hermann, Missouri to Confluence with Mississippi River | | | | |
| 92.5 | X | | | |
| 86.2 | | X | | |
| 82.0 | | | | X |
| 66.0 | | | | X |
| 56.5 | X | | | |
| 54.2 | | | X | |
| 35.2 | | | | X |
| 25.0 | | | | X |

2. Channel Scour and Deepening

During the first wave of the 1993 Flood, soundings from the USGS discharge measurements were compared against the last hydrographic survey made by the District in 1987. This comparison indicated that some 8 to 10 feet of scour had occurred from St. Joseph to Hermann, Missouri. Hydrographic measurements made in early 1994 by private consultants for highway corridor hydraulic studies above Lexington and at Jefferson City, Missouri, indicate that a scour of some 8 feet still exists below the 1987 hydrographic surveys. If some of the soundings made by the USGS during the discharge measurements are used for making a relative comparison, then at Kansas City, Missouri, on 12 July the deepest part of the channel, the thalweg, was at elevation 692.9 feet m.s.l. On 28 July, after the crest had passed, the deepest part of the channel was at elevation 678.2 feet, m.s.l., or some 14.7 feet below the 12 July bed elevation. By 12 August 1993, the measurements show that the bed had recovered somewhat to elevation 686.3 feet, m.s.l., or some 6.3 feet below the 12 July bed elevation. At Boonville, the same type of analysis indicates that the bed first scoured some 4 feet, then aggraded some 10 feet, then rescoured some 12 feet, or 2 feet below the start of the comparison bed elevation. Very limited data are available for St. Charles, Missouri, but data available indicate the bed was lowered some 4.3 feet from 24 July through 5 August 1993. The most startling phenomena that occurred at this site was the development of anti-dunes forming, moving upstream, breaking, and reforming. During these discharge measurements, point velocities in the range of 17 feet per second were quite common in the channel. Froude numbers of 0.40 to 0.42 existed from 1 through 4 August before declining to more common values around 0.2 to 0.25.

The above is a cursory examination of some of the data available. A much more detailed investigation should be undertaken to fully understand what channel damage was incurred by the attendant bed load transport during the 1993 Flood.

## G. Sedimentation

1. Missouri River

Large amounts of sediment were transported during the 1993 Flood. Large volumes of sand were deposited on and scoured from the floodplain over the course of the Missouri River from Rulo, Nebraska to its mouth. The adverse effects to agricultural areas are significant. Photographs 3 and 4 show typical sand deposits.

In the fact sheet "Impacts of the 1993 Flood on Missouri's Agricultural Land," published by the Soil Conservation Service, the following figures come from a study of cropland in the floodplains along the Missouri River in Missouri:

1) 455,000 acres (60 percent of the cropland in the Missouri River floodplain) were damaged by sand deposits and scouring. The sand deposits total more than 546 million cubic yards;

2) 237,000 acres (52 percent of the damaged acreage in the floodplain) are covered with up to six inches of sand;

3) 77,500 acres (17 percent of the damaged acreage) are covered with 6 to 24 inches of sand;

4) 59,000 acres (13 percent of the damaged acreage) are covered with more than 24 inches of sand;

5) 81,500 acres (18 percent of the damaged acreage) have been damaged by scouring.

The U.S. Geological Survey (USGS) made some preliminary estimates for the volume of suspended sediment that passed the gage at Hermann between 26 June and 14 September. The volume amounted to 76.8 million tons and was differentiated by gradation of 21.8 million tons of sand and 55.0 million tons of silt and clay.

2. Sedimentation in Lakes

a. Surveys

Reconnaissance surveys were completed during July through October 1993 on the following lakes: Tuttle Creek, Milford, Perry, Kanopolis, and Hillsdale in Kansas; Smithville in Missouri; and Rathbun in Iowa. The purpose of these surveys was to estimate the impact of the 1993 Flood on sediment inflow and incremental storage loss due to this event.

The results of these surveys are summarized in Table 12. To be consistent, the major sediment contribution was assumed to begin on 1 May 1993. The two exceptions in the table are Tuttle Creek and Kanopolis Lakes which were each surveyed twice in 1993. In 1993, the first resurvey of Tuttle Creek lake was in June and the first resurvey of Kanopolis Lake was in April. Therefore, the sediment deposited in between the surveys is event dependent.

b. Kanopolis Lake

In April 1993, a partial resurvey of the aggradation ranges at Kanopolis Lake was completed for the Kansas Water Office. A second resurvey of Kanopolis Lake was conducted in August 1993 to determine the impact of the 1993 Flood event on sediment deposition in the project. All ranges were surveyed. The estimated storage loss in Kanopolis Lake between April 1993 and August 1993 was 1,100 acre-feet.

c. Tuttle Creek Lake

Two resurveys were performed at Tuttle Creek Lake during 1993. The first resurvey was performed in June after the 1993 Flood event had started. The second resurvey was performed in September. The estimated storage loss between these two surveys was 2,600 acre-feet.

d. Milford Lake

In August 1993, a resurvey of the aggradation ranges in the multipurpose pool of Milford Lake was performed. The results of this survey indicate that the storage loss at Milford Lake from August 1987, the last reconnaissance survey, through August 1993 was 11,000 acre-feet. During the operation of the reservoir from closure in 1964 to the resurvey of 1980, the average annual rate was 1,840 acre-feet per year.

e. Perry Lake

A reconnaissance survey of the multipurpose pool of Perry Lake was also performed in August 1993. The storage loss at Perry Lake from August 1989, the last reconnaissance survey, through July 1993 was about 9,200 acre-feet. During the operation of the reservoir from closure in 1966 to the last official resurvey in 1979, the average annual rate of loss was 1,930 acre-feet per year.

f. Smithville Lake

A resurvey was performed in August 1993 on Smithville Lake. The storage loss from May 1989, the last official resurvey, through August 1993 was approximately 1,970 acre-feet. The estimated average annual storage loss rate between the first survey in October 1980 and the first official resurvey in May 1989 was 350 acre-feet per year.

g. Hillsdale Lake

The reconnaissance survey of Hillsdale Lake was performed in September 1993 and was the first reconnaissance survey. There has never been an official resurvey of this lake since closure in 1980. The estimated loss from the date of closure to the reconnaissance survey was approximately 1,930 acre-feet.

h. Rathbun Lake

The reconnaissance survey of Rathbun Lake was performed in October 1993. The average annual storage loss from closure in 1967 to the first official resurvey in May 1980 was 650 acre-feet per year.

**Table 12**
**Summary of Sedimentation Surveys - 1993**

| Project | Closure Date | Multi-Purpose Pool (ac-ft) | Sediment Allocation (ac-ft) | 1993 Reconn Survey Date | Storage Loss since Closure[1] (ac-ft) | Loss during 1993 flood (ac-ft) |
|---|---|---|---|---|---|---|
| Kanopolis | 1946 | 73,200 | 58,000 | 8/10-11 | 28,700 | 1,100 |
| Milford | 1964 | 415,400 | 160,000 | 8/24-25 | 65,300 | 800 |
| Tuttle Ck. | 1959 | 425,300 | 233,000 | 9/7-10 | 164,100 | 2,600 |
| Perry | 1966 | 243,100 | 140,000 | 8/5-6 | 49,000 | 4,000 |
| Hillsdale | 1980 | 76,300 | 11,000 | 9/21-23 | 1,900 | 100 |
| Smithville | 1976 | 144,600 | 52,300 | 8/18-22 | 5,000 | 600 |
| Rathbun | 1967 | 205,400 | 24,000 | 10/18-22 | 15,400 | 800 |

[1] Includes storage loss during 1993 flood.

## H. Structural Performance of Dams

### 1. General

The District's dam surveillance plans identify three different categories of surveillance (critical, increased and routine) depending on the pool levels. During the latter part of July, eight dams were under critical surveillance, seven were under increased, and three were under routine. Significant activities and observations at each of the projects under critical surveillance are discussed below.

#### a. Milford Dam

Twenty-four hour surveillance was initiated at Milford Dam on 12 July when the pool reached new record levels. District personnel performed surveillance activities and evaluated instrumentation data. In general, the dam embankment performed extremely well. Piezometer data and visual observations indicated the recently installed pressure relief wells, along with the buried collector pipe, were quite effective at controlling uplift pressures and avoiding some of the seepage related problems that had been experienced during the last record pool in 1973.

The outlet works was opened to maximum discharge (22,500 cfs) on 19 July as the reservoir approached top-of-flood control elevation. Within the first few hours, severe erosion had occurred on the left bank immediately downstream of the stilling basin and along the right bank several hundred feet downstream. Photograph 5 shows the Milford Lake outlet channel erosion. Once the channel riprap failed, the valley alluvium (silts and sands) eroded at an extremely high rate resulting in large losses of bank material. The left bank erosion was of primary concern due to its proximity to the embankment. Continued erosion in this area could have provided an uncontrolled exit point for underseepage, possibly resulting in a piping situation. The District initiated an emergency repair with a local contractor. The temporary repair involved regrading the eroded bank and placing large stone over filter fabric. It was very fortunate that a nearby quarry had a ready supply of large rock (48 inch diameter), as Milford Dam does not yet have an engineered rock stockpile. Outlet releases were decreased to 5,000 to 10,000 cfs during the repair, but upon completion were increased to 15,000 cfs.

The District is working to establish a permanent solution for the outlet channel. The Corps-Wide Committee on Channel Stabilization made a site visit 27-29 October 1993 and provided an interim report in late December. In general, it is evident that considerable hydraulic analyses are required to evaluate various alternatives. The District is currently revising its plan of work to incorporate the Committee's recommendations. Funding in the amount of $2.0 million is available for the repair from the 1993 Emergency Supplemental Appropriations for Midwest Flooding.

On 20 July, the lake elevation rose to 1177.3 feet as it started over the spillway crest (elevation 1176.2 feet). The maximum discharge through the spillway was estimated to be 20,000 cfs. Water ran over the spillway crest from 20 July to 3 August. On 23 July, about 6 p.m., State Road Spur 244, approximately 1,600 feet downstream of the control sill, washed out. At 7 a.m. on 24 July, head cutting was first observed in the spillway channel. By 11 a.m. that day, the head cutting was within 1,060 feet of the control sill. When flow over the spillway ceased on 3 August, the head cutting was within about 550 feet of the sill. The majority of the erosion appeared to follow an old drainage pattern that existed prior to spillway construction. Erosion in this old ravine occurred rapidly, but once this was eroded out, the head cutting continued, but at a much slower rate. Photograph 6 shows the erosion of the uncontrolled spillway at Milford Dam.

b. Tuttle Creek Dam

Twenty-four hour surveillance at Tuttle Creek Dam began on 10 July, when the pool reached elevation 1125.0 feet, and continued for more than a month.

Numerous seeps were observed in both abutments and along the toe of the embankment. In general, such seeps were anticipated as many had been previously identified at lower pools. Visual observation of the toe area was hampered during the highest lake levels due to inundation from spillway discharges. Piezometric and well flow data indicated that recently installed relief wells performed well at controlling underseepage. There were, however, several observation wells that indicated a slight build up of water in the downstream pervious embankment material near the left abutment. A review of historic data indicated that a similar build-up had occurred during the previous record pool in 1973. While the water levels measured to date have not been high enough to endanger the embankment, there is concern that the pervious drain outlet may have become contaminated over time and is no longer free draining. The District plans to rehabilitate the drain outlet. Releases through the spillway were started on 19 July and continued through 6 August. The spillway gates were raised incrementally during this time up to a maximum of 4 feet for the peak discharge of 60,000 cfs. The flows eroded an estimated 380,000 cubic yards of material from the unlined chute downstream of the spillway slab. Photographs 7 and 8 show the spillway in operation and the results of that operation, respectively.

c. Wilson Dam

Critical surveillance extended from 12 July through 28 October, including several weeks of 24-hour surveillance. A geotechnical engineer was on site daily from mid-July to mid-September.

As the pool reached record levels, a piezometer on the left abutment was noted to indicate rather high piezometric levels at the interface between the foundation overburden and underlying sandstone. Concentrated seeps were observed in the area. There was concern that the upper portions of the sandstone were weathered and susceptible to internal erosion. The area had poor access, so an access road was constructed to ensure capability to respond should the situation worsen. Project personnel installed several well points in the area, but difficulties were encountered in penetrating the sandstone. Eight additional pressure relief drains were installed into the rock itself by District drill crew personnel. These drains successfully decreased the piezometric levels in the immediate area.

In October 1993, the District installed four more piezometers in the left abutment area, as well as two in the right abutment to more fully investigate the nature of the seepage. Data are currently being obtained to determine the relationship between pool and piezometric levels.

Trilateration surveys revealed some movements in the embankment crest near the right abutment as the pool receded. Maximum movement was found to be about 0.5 ft. of settlement and 0.3 ft. upstream horizontal movement between 10 August and 29 September. Continued surveys showed some additional movement, but at a decreasing rate. Undisturbed foundation overburden samples were obtained and sent to Missouri River Division lab for testing to evaluate whether such movement could be a result of consolidation due to wetting. The lab results are currently being evaluated. Pending the results, additional investigation may be warranted to ensure the movement was not a result of slope instability due to draw down.

d. Perry Dam

Critical surveillance, including 24-hour operation, began on 22 July and lasted for approximately 2 weeks. Corps personnel performed surveillance activities and evaluated instrumentation data. Visual observation and instrumentation data generally indicated that the dam performed as anticipated.

Prior to the event, the spillway had some irregularities, including a windrow of soil immediately downstream of the sill and an abandoned access road further downstream. As reservoir levels approached the spillway crest elevation, project personnel regraded these irregularities to improve flow conditions and minimize erosion should a spillway release occur. The pool peaked at 1.1 ft. below the spillway crest so a spillway release did not occur.

e. Rathbun Dam

Critical surveillance was initiated on 9 July and was continued for slightly over two months, half of which involved 24-hour surveillance. Geotechnical personnel were on site daily during this entire period to assist with surveillance, read relief well flows, and evaluate piezometric data.

The primary area of concern was the left abutment which had experienced seepage problems in 1992 requiring a temporary rock berm to be constructed at the downstream toe of the embankment. Daily piezometric readings in this area indicated high piezometric levels existed downstream of the rock berm (downstream of the toe road). Project personnel constructed a second rock berm in this area to provide adequate protection against uplift pressures. A buried seepage collector system will be constructed in this area in 1994. The pool level barely exceeded the top of the sill of the spillway resulting in a flow of only 8 cfs over the spillway.

f. Smithville Dam

Project personnel performed critical surveillance from 23 July to 4 August. Visual observation and instrumentation data indicated that the dam embankment performed as anticipated. However, piezometer levels in the foundation of the main dike were observed to show significant fluctuation with pool. Piezometric level versus pool relationships indicated that piezometric levels projected for higher pools exceeded those assumed during design. The downstream slope stability is being reevaluated with these higher piezometric levels. It is currently believed that the slope will have adequate factors of safety for maximum surcharge conditions even with these higher piezometric levels.

g. Kanopolis Dam

The project was under critical surveillance, including 24-hour operation, from 22 July to 8 August. A geotechnical engineer was on site daily during this time to assist in surveillance and evaluate piezometric data.

Generally, the dam performed as anticipated. As with previous high pools and wet weather conditions, there were several wet areas observed on the downstream slope. These wet areas have been determined to be the result of surface infiltration rather than seepage. Sand Creek, along the downstream toe of the dam, experienced some very large flows during the flood. These flows caused some minor erosion in the vicinity of devices intended to measure underseepage flowrates. Repairs are scheduled to be made during the summer of 1994.

Large releases through the outlet works (6,500 cfs) were made during an extended period of time which resulted in some damage to the grouted rock apron immediately downstream of the stilling basin. Repairs in this area may be made in 1994, pending availability of funds. There was also considerable erosion along the left bank further downstream, but it does not represent a dam safety concern.

The spillway sill had been covered with in excess of 1.5 ft. of earth fill since its construction. As the pool approached the sill elevation, the District initiated a contract to cut slots through this material. The lake peaked at 1.2 ft. below the spillway crest so a spillway release did not occur. All of the excess material in the vicinity of the sill was removed and wasted along the left sideslope several hundred feet upstream of the sill.

The pool level reached elevation 1505.7 feet in the summer of 1993. In 1951, damage occurred in the uncontrolled chute of the intake tower after the pool elevation reached 1508. An inspection was made after the pool dropped below the chute crest (elevation 1463). No damage was observed.

h. Pomona Dam

Project personnel conducted critical surveillance from 23 July to 16 August. The dam performed as anticipated. However, it was noted that the pervious drain outlet had become contaminated with silt and was no longer free draining. The District plans to install several window drains along the downstream toe to ensure that there is no build-up of water within the embankment.

i. Truman Dam

Beginning 1 August and ending 7 December, it was necessary to make spillway discharges that reached 36,000 cfs. During the month of October, the spillway discharge exceeded 35,000 cfs. for 27 days.

In late December 1993, divers surveyed the stilling basin concrete erosion and investigated the outlet channel for evidence of erosion. The divers found 1 cubic yard of debris, approximately 2,700 pounds of exposed reinforcing steel and approximately 6 to 9 inches of additional concrete erosion (18 to 21 inches total) at isolated areas. The investigation of the outlet channel showed no signs of loose rock or erosion.

j. Dams under increased surveillance

Hillsdale, Clinton, Long Branch, Melvern, Stockton, Truman, and Pomme de Terre were all under increased surveillance during the flood. Clinton Lake reached a record pool in May and Pomme de Terre and Stockton Lakes reached record pools late in September. All of these dams were found to perform as designed during the high pools.

## V. Reservoir Regulation

The District is responsible for regulation of flood control storage at 18 Corps lake projects and 11 Bureau of Reclamation reservoir projects in the lower Missouri River basin (below Rulo, Nebraska, on the Missouri River). The location of each project is shown on Plate 1. The 11 Bureau reservoirs and seven of the District lakes are located in the Kansas River basin. The other 11 District lakes are located either in the Osage River basin (six), on small tributaries to the Missouri River in the metropolitan Kansas City area (three), or in the Chariton River and Little Chariton River basins (two). In general, regulation of flood control storage at each lake consists of storing inflows whenever downstream rivers are above flood stage to reduce downstream peak river stages and thus prevent additional flood damages; and evacuating (releasing) the stored inflows from the flood control pool as soon as possible as downstream channel capacities and flow conditions permit. This system of 29 operating lakes and reservoirs in the lower Missouri River basin has a total storage of 12.9 million acre-feet available for flood control, with 11.0 million acre-feet in the District projects and 1.9 million acre-feet in the Bureau projects.

## A. Preflood Conditions

Antecedent wet and cool meteorological conditions, including the major storms that persisted throughout the lower Missouri River basin and upper midwest, are described in Section III. The antecedent conditions culminated in high spring runoffs that began the Great Flood of 1993. Due to downstream flooding conditions on the Missouri River in May and June, the lakes and reservoirs in the lower Missouri River basin began to store inflows in their flood control pools. By 1 July, the storage available for flood control was reduced by 8.1 percent at the District lakes (971,400 acre-feet) and 5.8 percent at the Bureau reservoirs (148,500 acre-feet).

## B. Discussion of Project Water Control

### 1. General

The cumulative effects of preflood conditions and occurrence of much above normal precipitation throughout the period of 1 - 24 July resulted in record breaking floods on many streams in the lower Missouri River basin. Due to prolonged duration of flooding conditions on the Missouri River, several District lakes filled to capacity and spillway discharges were required while downstream flooding was still occurring. Nine District lakes reached new record storage levels, with four lakes exceeding the top of flood control pool. Four Bureau reservoirs reached record storage levels and one reservoir exceeded the top of flood control pool. During the 1993 Flood, the District system of 29 tributary lakes and reservoirs withheld a total of 10.0 million acre-feet of storage for flood control purposes, with 9.1 million acre-feet in the District lakes and 0.9 million acre-feet in the Bureau reservoirs.

### 2. Kansas City District Lake Projects

All 18 District lake projects stored water in their flood control pools during the 1993 Flood. The maximum pool level that occurred at each District lake is listed in Table 13. As noted in the table, the highest pool level of record occurred at nine District lake projects in 1993. The maximum pool level exceeded the top of flood control pool at the Milford, Perry and Tuttle Creek Lakes in the Kansas River basin and at Rathbun Lake on the Chariton River in Iowa. Water was stored in the surcharge pool and discharge through the spillway was required for the first time at the Milford, Tuttle Creek and Rathbun Lakes. At Perry Lake, the record level was three-tenths of a foot above the top of flood control pool and 1.1 feet below the spillway crest.

## Table 13
## Corps of Engineers Lakes & Reservoirs
## 1993 Maximum Pool Elevations

| Project | 1993 Maximum Pool Level | | Prior Maximum Pool Level | |
|---|---|---|---|---|
| | Elevation (ft., m.s.l.) | Date | Elevation (ft., m.s.l) | Date |
| Kansas River Basin | | | | |
| Harlan County | 1951.6 | 7/31/93 | 1955.7 | 4/09/60 |
| Milford ** | 1181.9 | 7/25/93 | 1170.0 | 10/17/73 |
| Wilson ** | 1548.2 | 8/13/93 | 1528.1 | 4/27/87 |
| Kanopolis | 1505.7 | 7/26/93 | 1507.0 | 7/14/51 |
| Tuttle Creek ** | 1137.7 | 7/23/93 | 1127.9 | 10/18-20/73 |
| Perry ** | 920.9 | 7/25/93 | 917.1 | 10/19/73 |
| Clinton ** | 887.7 | 5/17/93 | 886.8 | 6/04/82 |
| Kansas City Metro Area | | | | |
| Smithville ** | 874.3 | 7/28/93 | 873.2 | 10/16-17/85 |
| Blue Springs | 806.0 | 9/26/93 | 816.4 | 5/17/90 |
| Longview | 896.0 | 9/25/93 | 903.4 | 5/16/90 |
| Chariton River & Little Chariton River Basins | | | | |
| Rathbun ** | 927.2 | 7/28/93 | 924.5 | 6/22/82 |
| Long Branch | 799.0 | 7/26/93 | 799.6 | 7/28/81 |
| Osage River Basin | | | | |
| Melvern | 1048.3 | 7/29/93 | 1049.0 | 6/02/82 |
| Pomona ** | 992.7 | 7/31-8/1/93 | 990.2 | 6/02/82 |
| Hillsdale | 926.7 | 7/29/93 | 928.5 | 10/21/86 |
| Stockton | 884.5 | 9/28/93 | 885.9 | 4/28/73 |
| Pomme de Terre ** | 864.6 | 9/27/93 | 862.4 | 4/30/73 |
| Harry S. Truman | 735.2 | 8/2/93 | 738.7 | 10/26/86 |

** Lakes with highest pool level of record occurring in 1993

3. Bureau of Reclamation Reservoir Projects

Regulation of flood control storage at the 11 Bureau of Reclamation projects in the Kansas River basin is accomplished by the District through close coordination with the Bureau of Reclamation. Seven of the Bureau projects are located in the Republican River basin and the other four projects are located in the Smoky Hill River basin. The Republican and Smoky Hill Rivers join at their confluence to form the Kansas River. As shown in Table 14, the maximum pool elevations in 1993 were the highest pool levels of record at four Bureau reservoir projects. The maximum pool level at Lovewell Reservoir exceeded top of flood control pool by less than one-tenth of a foot.

**Table 14**
**Bureau of Reclamation Reservoir Projects**
**1993 Maximum Pool Elevations**

| Project | 1993 Maximum Pool Level | | Prior Maximum Pool Level | |
|---|---|---|---|---|
| | Elevation (ft., m.s.l.) | Date | Elevation (ft.,m.s.l) | Date |
| Republican River Basin | | | | |
| Bonny | 3671.9 | 6/06/93 | 3678.1 | 5/17/57 |
| Swanson | 2752.3 | 6/14/93 | 2757.4 | 8/2-3/62 |
| Enders | 3101.6 | 6/24/93 | 3118.2 | 4/25/60 |
| Hugh Butler | 2580.6 | 7/30-31/93 | 2584.1 | 7/15-16/67 |
| Harry Strunk | 2371.4 | 7/28/93 | 2374.1 | 3/23/60 |
| Keith Sebelius | 2296.0 | 7/28-31/93 | 2304.6 | 6/27/67 |
| Lovewell ** | 1595.3 | 7/22/93 | 1595.0 | 10/13/73 |
| Smoky Hill River Basin | | | | |
| Webster ** | 1904.3 | 10/17/93 | 1899.7 | 6/09/91 |
| Kirwin ** | 1734.4 | 11/08/93 | 1732.1 | 6/09/61 |
| Waconda ** | 1487.0 | 7/29/93 | 1471.3 | 4/27/87 |
| Cedar Bluff | 2117.2 | 7/30-31/93 | 2154.9 | 7/4-5/57 |

** Lakes with highest pool level of record occurring in 1993

4. Storage Utilized at District Lakes

The maximum amount of storage utilized for flood control purposes at each District lake project during the 1993 Flood is presented in Table 15. The District lakes utilized a total storage of 9,123,500 acre-feet which includes 333,000 acre-feet of surcharge storage. The total storage in the flood control pools of 8,790,500 million acre-feet is equivalent to 79.7 percent of the total flood control storage for the 18 District lakes located in the lower Missouri River basin.

**Table 15**
**Kansas City District Lakes & Reservoirs**
**Storage Utilized in 1993 for Flood Control**

| Project | Total Flood Control Storage (ac.ft.) | 1993 Flood Data | | |
|---|---|---|---|---|
| | | Total Storage Utilized[1] (ac.ft) | Percent Total F.C. Storage | Surcharge Storage Utilized (ac.ft) |
| Kansas River Basin | | | | |
| Harlan County | 496,700 | 80,500 | 16.2 | |
| Milford * | 756,700 | 957,500 | 126.5 | 200,800 |
| Wilson | 530,200 | 421,200 | 79.4 | |
| Kanopolis | 369,300 | 337,900 | 91.5 | |
| Tuttle Creek * | 1,922,100 | 2,012,800 | 104.7 | 90,700 |
| Perry * | 516,000 | 523,000 | 101.4 | 7,000 |
| Clinton | 268,400 | 103,000 | 38.3 | |
| Subtotals | 4,859,400 | 4,435,900 | 90.1 | 298,500 |
| Kansas City Metro Area | | | | |
| Smithville | 101,800 | 83,400 | 81.9 | |
| Blue Springs | 15,700 | 3,050 | 19.3 | |
| Longview | 24,800 | 5,150 | 20.8 | |
| Subtotals | 142,300 | 91,600 | 64.4 | |

## Table 15
## Kansas City District Lakes & Reservoirs
## Storage Utilized in 1993 for Flood Control

| Project | Total Flood Control Storage (ac.ft.) | 1993 Flood Data | | |
|---|---|---|---|---|
| | | Total Storage Utilized[1] (ac.ft) | Percent Total F.C. Storage | Surcharge Storage Utilized (ac.ft) |
| Chariton River & Little Chariton River Basins | | | | |
| Rathbun * | 345,800 | 370,300 | 107.1 | 34,500 |
| Long Branch | 30,300 | 23,300 | 76.9 | |
| Subtotals | 376,100 | 393,600 | 104.7 | 34,500 |
| Osage River Basin | | | | |
| Melvern | 208,200 | 104,300 | 50.1 | |
| Pomona | 176,500 | 98,300 | 55.8 | |
| Hillsdale | 83,600 | 53,200 | 63.6 | |
| Stockton | 776,100 | 507,200 | 64.0 | |
| Pomme de Terre | 406,800 | 268,300 | 65.9 | |
| Harry S. Truman | 4,005,900 | 3,171,100 | 79.2 | |
| Subtotals | 5,657,100 | 4,202,400 | 74.3 | |
| Totals | 11,034,900 | 9,123,500 | 82.7 | 333,000 |

[1] Storage utilized includes surcharge storage
* Lake projects with water stored in surcharge zone

Storage levels at the District lakes in the Kansas River basin peaked in late July and early August, with the exception of Clinton Lake. Clinton Lake peaked in May and although most of the stored inflows were evacuated by 1 July, the pool level nearly reached the May level in late July. The total maximum storage of 4,435,900 acre-feet withheld at the seven District lakes is a new record total storage amount for the Kansas River system of District lakes, and is equivalent to 90.1 percent of the total flood control storage in the system.

The Rathbun Lake on Chariton River, Long Branch Lake on Little Chariton River and Smithville Lake in the Kansas City metropolitan area also reached maximum storage levels in late July and the flood control storage utilized varied from 76.9 to 107.1 percent. The storage levels in the Blue Springs and Longview Lakes in the Kansas City metropolitan area reached only about 20 percent of total flood control storage. In the Osage River basin, four of the lake projects peaked in late July or early August and the other two projects peaked in September. Although the Stockton, Pomme de Terre, Longview and Blue Springs Lakes reached maximum storage levels in September, they were also effective in reducing downstream peak stages in late July and early August.

The maximum amount of storage used on a given day in the District lake and reservoir system was 8.6 million acre-feet which occurred on 1 August. This amount of total system storage is about 0.5 million acre-feet less than the total maximum storage of 9.1 million acre-feet stored by the District lakes during the Flood of 1993. This difference is primarily due to water stored at several lake projects, either in May or September, which was slightly greater than that stored at the same several lakes in July or August.

5. Storage Utilized at Bureau Projects

The maximum amount of storage utilized for flood control purposes in 1993 is presented in Table 16 for each Bureau reservoir project. A total maximum storage of 918,200 acre-feet was stored after 1 May in the Bureau projects. This storage includes water stored in the irrigation and multipurpose pools as well as the flood control pools. Maximum storage levels occurred in June or July, except at Webster and Kirwin Reservoirs, where the maximum storage occurred in October and November, respectively. Because a majority of the Bureau projects were well below the base of flood control pool for a number of years, a considerable amount of flood control benefit was obtained from the refilling or nearly refilling of the irrigation and multipurpose pools. The multipurpose pool was filled and water was stored in the flood control pool at six of the 11 Bureau projects. The average storage in the irrigation and multipurpose pools on 1 May was 48.6 percent for the four projects in the Smoky Hill River basin and 84.3 percent for the seven projects in the Republican River basin. During the 1993 Flood, the average storage in the irrigation and multipurpose pools was filled up to a maximum of 88.9 percent for the Smoky Hill River projects and 88.2 percent for the Republican River projects.

### Table 16
### Bureau Reservoir Projects
### Storage Utilized for Flood Control

| Project | Total Flood Control Storage Available (ac-ft) | 1993 Flood Data | |
|---|---|---|---|
| | | Storage Used 1 May to Maximum (ac-ft)[1] | Percent of Total F.C. Storage Used |
| Republican River Basin | | | |
| Bonny | 128,800 | 700 | 0.0 |
| Swanson | 134,100 | 8,300 | 1.2 |
| Enders | 30,000 | 2,100 | 0.0 |
| Hugh Butler | 48,900 | 3,500 | 0.0 |
| Harry Strunk | 52,700 | 10,400 | 20.5 |
| Keith Sebelius | 98,800 | 2,200 | 0.0 |
| Lovewell | 50,500 | 45,600[2] | 100.4 |
| Subtotals | 543,800 | 72,800 | |
| Smoky Hill River Basin | | | |
| Webster | 183,400 | 98,700 | 28.5 |
| Kirwin | 215,100 | 81,600 | 12.9 |
| Waconda | 722,300 | 621,500 | 94.1 |
| Cedar Bluff | 191,900 | 43,600 | 0.0 |
| Subtotals | 1,312,700 | 845,400 | |
| Totals | 1,856,500 | 918,200 | |

[1] Includes empty multipurpose storage space used to store floodwater
[2] 5,100 ac-ft of flood control storage filled prior to 1 May 1993

## 6. Inflow/Outflow/Pool Stage Hydrographs

Inflow, outflow and pool elevation hydrographs for each District lake are shown on Plates 108 thru 125 for the period of 1 May through 30 October 1993. Specific information on regulation of flood control storage at each District lake is discussed in following paragraphs by pertinent river basins or metropolitan area. The long duration of about 50 days for the Missouri River to be above flood stage resulted in a large buildup of storage within the District lakes and led to operational difficulties in attempting to evacuate (release) stored inflows before reaching the top of flood control pool. This resulted in three projects in the Kansas River basin storing inflows in the surcharge pools.

a. Kansas River Basin

1) Harlan County Lake. The maximum pool level of elevation 1951.6 feet occurred on 31 July.

2) Milford Lake. Large inflows in July on the Republican River caused the pool level to exceed top of flood control, elevation 1176.2 feet, on 19 July and reach a new record elevation of 1181.9 feet on 25 July. Precipitation at the lake in July totaled 11.5 inches. Average inflow for July was about 21,600 cfs and maximum daily inflows over 40,000 cfs occurred on 9 July and 24 July. The major pool level rise began on 25 June and it receded to that level on 15 September for a total period of 82 days. No releases were made between 2 and 16 July. The maximum discharge of 35,000 cfs occurred on 25-26 July with outflow through the uncontrolled spillway (20,000 cfs) and outlet works (15,000 cfs). Water flowed through the spillway for 14 days from 20 July to 3 August (surcharge operation). The maximum pool level was 5.7 feet above top of flood control pool and a total surcharge storage of 200,800 acre-feet was utilized.

3) Wilson Lake. Large inflows in late June and July on the Saline River caused the pool level to reach an elevation of 1548.2 feet on 13 August. This pool level is 20.1 feet higher than the previous maximum pool elevation of 1528.1 in April 1987. The pool level rise occurred over a period of about 50 days.

4) Kanopolis Lake. The maximum pool elevation of 1505.7 feet occurred on 26 July. During the period of 26-31 July, the outlet works discharge was increased 1,500 cfs to 6,500 cfs to prevent surcharge operation.

5) Tuttle Creek Lake. Large inflows in July on the Little Blue and Big Blue Rivers caused the pool level to exceed top of flood control, elevation 1136.0 feet, on 20 July and reach a new record elevation of 1137.7 feet on 23 July. The project was in surcharge operation for six days. Precipitation at Tuttle Creek Lake in July totaled 15.6 inches, average inflow for the month was about 42,000 cfs and a maximum daily inflow over 90,000 cfs occurred on 6 July. The maximum discharge of 60,000 cfs was made through the gated spillway on 23 to 26 July. The pool began to rise on 25 June and did not recede to that same level until 19 September, a period of 86 days. Minimum releases were made from 1 to 19 July.

6) Perry Lake. Large inflows into the lake on the Delaware River during July caused the pool level to exceed top of flood control, elevation 920.6 feet, on 24 July and reach a new record elevation of 920.9 feet on 25 July. The project was in surcharge operation for three days. Precipitation in July totaled 16.1 inches, average inflow for the month was about 8,500 cfs, and a maximum discharge of 10,000 cfs was made through the outlet works from 11 to 27 August. The major rise in pool began on 1 July. It did not recede to that same level until 30 August, a duration of 61 days. From 2 to 25 July, minimum releases were made.

7) Clinton Lake. Large inflows in April and May caused the pool level to reach a new record elevation of 887.7 feet on 17 May. The maximum discharge of 4,000 cfs was made on 22 to 24 May. Large inflows in July once again caused the pool level to rise to elevation 887.6 feet on 31 July, about one tenth of a foot below the prior maximum pool in May. No releases were made from 2 July to 9 August. Precipitation at Clinton Lake during the months of April, May and July was 6.9, 6.7, and 14.8 inches, respectively.

b. Kansas City Metro Area

1) Smithville Lake. Above average inflows in July caused the pool to reach a new record elevation of 874.3 feet on 28 July. Precipitation in July totaled 13.4 inches with a daily average inflow of 1,250 cfs. The major rise of the pool began on 29 June and the pool did not recede to that same level until 28 August, a period of 61 days. No releases were made from 29 June to 28 July.

2) Blue Springs Lake. The 1993 Flood had the least impact on flood control storage at this lake project compared to all other District lakes. The maximum pool elevation of 805 feet in July represents only three feet of flood control storage.

3) Longview Lake. The maximum pool level elevation of 895.5 feet (4.5 feet of flood control storage) and the maximum release of 1,050 cfs occurred on 7 July. During the month of July, precipitation at Longview Lake totaled 10.1 inches.

c. Chariton River & Little Chariton River Basins

1) Rathbun Lake. Intense rainfall occurred on 14-15 September 1992 resulting in an average rainfall over the drainage area of about 12 inches. On 20 September 1992, the pool level crested at elevation 922.8 feet, some 18.8 feet into the flood control pool. The peak inflow was 73,250 cfs on 16 September 1992, which is the maximum of record. Evacuation of accumulated flood storage lowered the pool to elevation 907.7 feet by 2 March 1993.

The above antecedent conditions, combined with average to above average rainfall during the period of March through June resulted in a rising pool during that period. The pool level was at elevation 911.2 feet by 30 June, 7.2 feet above the multipurpose pool.

Heavy rains in July produced high inflows into Rathbun Lake. The high inflow, combined with the already high pool level, produced the maximum pool level of record. Rathbun Lake crested on 28 July at elevation 927.2 feet, some 1.2 feet into the surcharge pool. The maximum discharge through the uncontrolled spillway was only 8 cfs and the pool level was in surcharge operation for 12 days.

2) Long Branch Lake. Very heavy rainfalls resulted in high inflow (7,800 cfs) during the first three days of July and during the period of 24-25 July. These high inflows produced the maximum pool level on 26 July at elevation 799.0 feet, some 8.0 feet into the flood control pool, which represents approximately 77 percent of the total flood control storage. This maximum pool level is the third highest of record.

d. Osage River Basin

1) Melvern Lake. Moderate to heavy rainfall, combined with high antecedent conditions, resulted in high inflow during the second week of May, forcing the pool to rise over 9.0 feet into the flood control pool. Accumulated flood storage was essentially evacuated by the first of July. Heavy rainfalls, resulted in high inflow during the third week in July and produced the maximum pool level of elevation 1048.3 feet on 29 July. This level was some 12.3 feet into the flood control pool and it has been exceeded only by the June 1982 flood, which reached a maximum pool level of elevation 1049.0 feet.

2) Pomona Lake. Moderate to heavy rainfall during the first half of May, combined with high antecedent conditions, resulted in high inflows, forcing the pool level to rise nearly 15.0 feet into the flood control pool by mid-May. This accumulated storage was essentially evacuated by mid-June. However, heavy rainfall resulted in high inflows during the third week of July 1993. This high inflow coupled with regulation restrictions on releases due to record breaking stages downstream on the Missouri River, produced the maximum pool level of record. The maximum pool elevation of 992.7 feet, some 17.7 feet into the flood control pool, occurred on 31 July. This pool elevation represents 56 percent of the total flood control storage. The maximum daily inflow was 14,100 cfs on 22 July.

3) Hillsdale Lake. Moderate to heavy rainfall during May combined with existing high antecedent conditions produced high inflows during the period of 7-10 May forcing the pool to rise 5.65 feet into the flood control pool by 17 May. The accumulated flood storage was evacuated by 21 June.

Heavy rainfall in July resulted in high inflow on three different occasions which produced the maximum pool level on 27 July at elevation 926.6 feet. This pool level represents about 64 percent of the total flood control storage. The crest in July was exceeded only by the October 1986 (maximum pool elevation of 928.5 feet) flood event.

4) Stockton Lake. The impact of the 1993 Flood on flood control storage was not significant at this lake project. The pool level remained near elevation 870.0 feet until the first week of July when outflow was restricted to 40 cfs due to record breaking flooding on the Missouri River and regulating criteria with the downstream Harry S. Truman Dam and Reservoir. The maximum summer pool of elevation 873.1 feet on 31 July represents only 6.1 feet (20.4 percent) of flood control storage. In late September,

the lake reached elevation 884.5 feet, which represents 64.0 percent of the flood control storage.

5) Pomme de Terre Lake. The impact of the 1993 Flood on flood control storage was not significant at this lake project. The maximum summer pool elevation of 844.6 feet on 29 July is only 5.6 feet of flood control storage. This small pool increase was due to restrictions in outflow for record breaking flooding on the Missouri River and regulating criteria with the downstream Harry S. Truman Dam and Reservoir. Like Stockton, Pomme de Terre reached its highest elevation of the year in late September. The maximum pool of 864.6 feet represents 65.9 percent of the flood control storage.

6) Harry S. Truman Dam and Reservoir. Moderate inflow during May forced the pool level to rise to elevation 716.9 feet by 20 May, some 10.9 feet into the flood-control pool. Evacuation of flood control storage was nearly complete at the end of June. Heavy rainfall in July (nearly 11.0 inches at the Truman Dam and Reservoir) resulted in above average inflow. This inflow, coupled with record breaking flooding on the Missouri River, required curtailed releases from the Harry S. Truman Project and produced the maximum 1993 pool level. Beginning on 2 July , spillway discharge outflow was restricted to 500 cfs to maintain the dissolved oxygen level in the gate-wells and downstream.

The maximum pool level occurred on 2 August at elevation 735.2 feet. This elevation was 29.2 feet into the flood control pool and the storage occupied represents 79.2 percent of the total flood control storage. Mean inflow during July averaged nearly 51,000 cfs.

## C. Problems

Regulation problems encountered during the 1993 Flood are discussed in the following paragraphs, primarily at those lake projects with pool levels near or above the top of flood control pool involving surcharge operation. It was necessary in some cases to make operational changes to water control plans that had been developed for the lake projects.

### 1. Rathbun Lake

An outlet works discharge of 1,500 cfs was initiated at noon on 24 July when the pool level was near top of flood control pool and crest of uncontrolled spillway, elevation 926.0 feet. Rathbun Lake crested on 28 July at elevation 927.2 feet, 1.2 feet into the surcharge pool, and a maximum discharge through the spillway of only 8 cfs was measured. Although the water control plan called for a total discharge of 1,500 cfs, the outlet works discharge was increased to 1,800 cfs on 28 July to more quickly lower the surcharge pool. The pool was lowered to top of flood control on 5 August for a total surcharge operation of 12 days.

2. Milford Lake

The Milford Lake pool level reached the top of flood control and the crest of the uncontrolled spillway of elevation 1176.2 feet on 19 July. As the pool entered the surcharge zone, the outlet works discharge was increased to 22,500 cfs. Very little or no water passed through the spillway until the pool reached elevation 1177.3 feet. On the evening of 19 July, severe erosion on the left bank of the outlet channel resulted in major concern over potential underseepage and related stability of the dam embankment. The outlet works discharge was immediately reduced to 15,000 cfs and subsequently to 5,000 cfs to stop further erosion of the left bank.

The eroded left bank area was inspected and a plan for emergency repair measures was formulated. The outlet works discharge was further reduced to 5,000 cfs to enable temporary riprap repair work to be completed. After the channel repair work was completed, it was found a maximum discharge of 15,000 cfs could safely be made through the outlet works; however, the water control plan requirement for discharge of 22,500 cfs could not be met. On 25 July, Milford Lake crested at elevation 1181.9 feet, 5.7 feet above the spillway crest (surcharge storage of 200,800 acre-feet). The pool was lowered to top of flood control pool on 3 August, for a total surcharge operation of 15 days.

3. Tuttle Creek Lake

The reservoir regulation plan was followed as the pool reached the top of flood control pool, elevation 1136.0, and rose into the surcharge zone on 20 July. Releases were adjusted, by using the outlet works and spillway, to increase the total release in accordance with surcharge operation during the period of 20 to 23 July when the pool crested at elevation 1137.7 feet, 1.7 feet above top of flood control pool. Based on inflow and surcharge operating criteria, the spillway gates were raised to a 4-foot opening and the total discharge was 60,000 cfs

The water control plan called for maintaining the 4-foot gate opening until the pool returned to the top of flood control pool, and then to resume normal operation. However, since the area downstream had been flooded by the 60,000 cfs discharge, it was the opinion of those in the downstream area that the releases should continue until inflow receded to lower levels which would provide additional flood control storage.

During this period of higher discharges through the spillway and outlet works, a concern regarding the stability of the stilling basin walls was noted, i.e., rather large differential levels between the phreatic levels behind the walls and the level in the stilling basin. It was determined that no releases should be made through the outlet works until the phreatic levels behind the walls reached a lower elevation, therefore the discharge of 5,000 cfs through the outlet works was discontinued on 22 July.

There was also concern regarding a rather large change in the water surface elevation in the stilling basin in relationship to the ground water levels near the base of the dam. For these reasons, the only discharge made was through the spillway. While the spillway gates were maintained at the 4-foot opening the spillway flow gradually receded to 15,000 cfs when the pool reached elevation 1120.4 feet on 9 August. At this time releases through the outlet works were allowed based on acceptable phreatic levels behind the stilling basin wall.

4. Perry Lake

An outlet works discharge of 5,000 cfs was started on 24 July. By that time, the pool level had exceeded top of flood control pool, elevation 920.6 feet. This discharge was slightly less than inflow, and the pool increased slightly to crest at elevation 920.9 feet on 26 July. This pool level was 1.1 feet below the crest of the uncontrolled spillway.

5. Smithville Lake

The outlet works discharge was gradually increased from 500 cfs on 28 July to 1,500 cfs on 30 July. At this time Smithville Lake had crested at elevation 874.3 feet, or 1.9 feet below the top of flood control pool and the lake was approximately 80 percent full.

6. Harry S. Truman Dam and Reservoir

In early August 1993, as the Missouri River stages at Hermann began to recede, releases were started with the objective of discharging a total of about 50,000 cfs to meet the target discharge of 54,000 cfs at St. Thomas, Missouri on the lower Osage River. At this time, only one of six turbines was available for use, as units one through five were out of service for repairs or declared unavailable for operation due to problems related to blocking of the blades during the mid to late 1980's. With required spillway discharges of 43,000 cfs for a total discharge of 50,000 cfs, it was anticipated that the flip lips on the spillway would be effective in reducing the deep plunge of the spillway discharge. However, when the spillway discharge reached 36,000 cfs, gas saturation levels measured 118 percent. Therefore, the spillway discharge was limited to 36,000 cfs so as not to place undue stress on the fish in the downstream headwaters of the Lake of the Ozarks.

The total discharge was further reduced to 30,000 cfs on 24 August. The purpose was to create a more rapid drop in the river stages along the lower Missouri River and the Mississippi River at St. Louis. The lower river stages would permit an earlier start on repair work for the damaged levees on the Missouri River. A further reduction to 15,000 cfs was made on 27 August. The total discharge was increased to 25,000 cfs on 9 September and to 34,000 cfs on 10 September. During the month of October, the total discharge exceeded 35,000 cfs for 27 days.

## D. Lessons Learned

1. Evaluation and Identification of Dam Safety Issues

a. Discussion

Most water control plans developed for flood control operation do not consider potential restrictions to the discharge capability of the spillways or outlet works that could occur when the pool level is at or near the top of flood control pool, or within the surcharge pool. Two examples of restrictions to discharge capability that occurred during the 1993 Flood are as follows:

At Milford Lake, it was necessary to reduce the outlet works discharge to stop further erosion from occurring in the outlet works channel. There was concern the high level discharge required by the water control plan would possibly threaten the integrity of the structure. The resulting pool level reached, due to restricted use of the outlet works, was higher than it would have been had the reduced discharge not been required.

At Tuttle Creek Lake, releases could not be changed back from the gated spillway to the outlet works as soon as required by the water control plan because of concerns about the stability of the stilling basin walls of the outlet structure. It was necessary to maintain the spillway discharge for a longer period of time so that the tailwater elevation at the outlet works could recede to an acceptable level. Releases through the outlet works could not be made until the phreatic levels behind the walls were reduced to acceptable levels.

b. Required Action

Project features such as outlet works, spillways, and outlet channels, should be critically evaluated for expected performance with respect to dam safety. Once concerns are identified they should be resolved so that water control plans can be implemented as required and not be limited by structural constraints, especially during critical periods of major flood events.

2. Spillway Rating Curves

a. Discussion

Based on conditions experienced during the Flood event of 1993, the present rating curves may reflect discharges that are too high for pool levels near the spillway crest up to as much as three feet above the crest. It was noted at Milford and Rathbun Lakes that pool elevations one to two feet above the crest were required to cause flow to begin through the uncontrolled spillways. This condition is not reflected in the spillway rating curves developed for these projects as the actual discharges were less than those shown on the rating curves. Spillway studies at Milford and Rathbun Lakes should be made to correct the present rating curves to reflect conditions experienced in 1993.

b. Required Action

The spillway discharge rating curve for each lake project with an uncontrolled spillway should be reevaluated for pool elevations near the spillway crest.

3. Coordination with Levee Districts

Earlier coordination with levee district officials should be established when levees and floodwalls are potentially threatened with overtopping.

4. Improve River Stage and Lake Level Forecasting

Include use of National Weather Service Quantitative Precipitation Forecasts to anticipate lake and river levels rather than just using current rainfall.

## VI. Coordination

Liaison officers (LNO) were dispatched to the State Emergency Operations Centers in Kansas and Missouri. The LNOs coordinated requests for supplies and equipment, briefed Governors and state officials on river stages, USACE activities/authorities, levee data, and utilizing National Guard assets to reposition sandbags and pumps.

Liaison officers were also deployed to Emergency Operations Centers (EOCs) in the communities of Manhattan and Junction City, Kansas, as well as to the EOC at Fort Riley, Kansas. The LNOs assisted local officials with identifying flood prone areas that would be impacted by releases from reservoirs.

Substantial coordination was on-going 24 hours a day, seven days a week for 37 days. The District's EOC, Public Affairs, Executive Office and Water Control Section processed over 41,300 telephone calls during the first thirty days of the flooding. Most of the callers were seeking information on river stages, levee elevations, and other related data.

Governors, state emergency management agencies, and other interested officials in the State governments were notified prior to releases from the dams and reservoirs that would impact on areas downstream. Coordination with state and local entities, levee sponsors, the National Weather Service, U. S. Coast Guard, FEMA, the National Guard, and military installations was intense. In addition, numerous private citizens were referred to local emergency officials regarding evacuation and other pertinent issues.

## VII. Emergency Response Activities

When the Great Flood began, no one could anticipate what would occur over the next several months or that the flood fight would go on 24 hours a day for 37 days, and then be scaled back to 12-hour days. A Kansas City woman best described it as "a disaster in slow motion."

Emergency response activities, from providing flood fighting supplies to providing cots for an evacuation shelter, were conducted throughout the entire Kansas City District. Most response activities, however, were concentrated along the Missouri and Kansas Rivers.

Emergency operations and recovery efforts went beyond the human resource capabilities of the District. Innovative ways were found to meet this shortage of personnel. Several retirees that were familiar with dams and levees were recalled to supplement the staff. In addition, sister Districts and Divisions responded to the call for assistance immediately, augmenting those skills where the District did not have adequate resources to effectively execute missions. The Bureau of Reclamation also responded well to a call for assistance. In all, over 100 temporary duty personnel supported the Kansas City District.

When it was finally over, the District had issued almost 6.9 million sandbags, loaned more than 100 water pumps, arranged for the delivery of more than 1,000 portable toilets, distributed numerous generators, arranged for the delivery and storage of potable water, and expended approximately $6,000,000.

### A. Advance Measures

No advance measures were taken.

### B. Flood Fight Activities

Numerous levee sponsors were provided technical assistance, sandbags, pumps, and flood fighting advice. Flood fight activities were conducted on three levee units, two Federal units and one non-federal levee. These efforts are described below.

1. North Kansas City Levee

The North Kansas City Levee (Airport Section) is located in Kansas City, Missouri and consists of a system of levees, floodwall, and appurtenances along the Missouri River. The south pumping plant was damaged during the May 1993 flood and as river stages continued to climb, contingency plans developed earlier were implemented and a contract was issued to expedite construction of a temporary ring levee to protect the Kansas City Downtown Airport, railroad yards, a business area, and other structures.

2. Missouri River Levee System (MRLS) L-246 Levee

MRLS L-246 Levee is located on the left bank of the Missouri River and includes three tributaries (Grand River, Chariton River and Mussel Fork). L-246 is a Federal project providing flood protection for 31,900 acres of land, homes, and other structures in and around the towns of Brunswick and Dalton, Missouri.

MRLS L-246 Levee began experiencing sloughing and slides as a result of saturated ground conditions from the continuous rain on 10 May when the river was above flood stage. As conditions continued to deteriorate, it was necessary to issue an emergency operations letter contract on 22 July to construct a rock access road to permit reinforcement of the levee embankment at two of the slide locations in an effort to preclude further damage. The unit was overtopped along the Grand River on 26 July and breached along the main stem levee on the Missouri River. Photograph 9 shows the L-246 Levee breach.

3. Monarch-Chesterfield Levee

The Monarch-Chesterfield Levee, a private levee, sustained a major breach in the upstream reach the night of 30 July during a period of rapidly rising water levels allowing headwater flows to inundate 5,632 acres, which includes the Chesterfield Industrial Park, the Spirit of St. Louis Airport, numerous farms, and portions of U. S. Highways 40 and 61. It was necessary to evacuate the entire interior area causing loss of hundreds of jobs, closing the second busiest airport in the State, as well as businesses and a major east-west thoroughfare.

Flood waters receded and initial clean-up operations commenced as well as expediting contracting procedures to proceed with the repair of the primary upstream breach. However, before the initial repairs could be initiated, additional heavy rainfall occurred throughout the basin causing another rise in river levels with a predicted crest that would again subject the interior area to headwater flow. The emergency situation necessitated a modification to the initial contract in an attempt to provide partial protection in the immediate vicinity. It quickly became evident that this effort would not be effective in the increasingly wet and muddy field conditions. A joint effort by the City of Chesterfield and St. Louis County was initiated to raise the elevation of a north-south road by hauling and placing rock by a contractor. The locals requested and were provided assistance from the District in the flood fight effort. Round-the-clock efforts resulted in holding back the headwater flow throughout the area and additional major devastation was averted.

**C. Evacuation Activities**

Gage readings and data on levees were furnished to FEMA and numerous other Federal, state, local and service agencies that were responsible for ordering evacuations and/or providing for those evacuated. District personnel were on-site in the St. Charles/St. Louis area closely monitoring the non-Federal levees and updating local EOCs on changing conditions. The liaison officers located in the Kansas EOCs also assisted local officials with identifying flood prone areas so that the officials could coordinate evacuation activities.

**D. Operations under the Federal Response Plan**

The Regional Operations Center (ROC) was activated in the FEMA Region VII office in Kansas City on 11 July. The District provided personnel to cover the 24-hour operation until such time as personnel from the Missouri River Division could arrive to assume the duties. Activation of the Federal Response Plan necessitated the District to provide logistical support to two Disaster Field Offices (DFO), one in the State of Kansas and one in the State of Missouri.

1. Missouri Missions

FEMA established the Missouri Disaster Field Office (DFO) on 14 July in Bridgeton, Missouri in an area known as Earth City. In mid-November, the DFO relocated to Jefferson, City, MO. In November, FEMA activated the Emergency Support Functions (ESF) necessary to support response in the State of Missouri. This group provided liaison/coordination and accepted mission assignments for its respective agencies in accordance with the Federal Response Plan. The Kansas City District representative was on site 14 July. The District representative brokered mission assignments to Lower Mississippi Valley Division (LMVD) and Missouri River Division (MRD) who subtasked the Kansas City, Nashville or Memphis District, to provide the contractual support to the communities involved.

The District EOC was advised at 2230 hours on 24 July that the City of St. Joseph, MO, on the Missouri River in Buchanan County in the northwestern corner of the state, had lost the use of its water supply system as a result of the flooding, and would be requesting Federal assistance to furnish water to the community. Early Sunday morning, 25 July, the Corps received the following ESF #3 Missions from FEMA to provide:

a. Containerized Water: Provide 100,000 gallons potable water in small containers (1, 2 1/2, and 5 gallon containers) to St. Joseph, MO by the same afternoon, 25 July.

b. Water Purification Units and Bladder Tanks: Deliver 43,000 gallons-per-day water purification unit to St. Joseph, MO no later than 26 July; delivery fifty-six 3,000 gallon "onion bag" bladders to St. Joseph on 27 July.

c. Report on National Guard/Army Assets: The only location for which any information was known was on the assets in St. Joseph. The Air National Guard manned the staging area at Missouri Western College for the duration of the water supply emergency.

d. Portable Toilets: Provide 350 portable toilets to the St. Joseph area. Units were expected to be used and serviced daily until the end of the emergency.

e. Bulk Water: Tasking was to provide 950,000 gallons of bulk potable water per day to the Missouri Western staging area. The water was off-loaded by the Missouri Air National Guard into smaller (1,500 gallon) tanks for distribution around the city.

f. Portable Toilets: A second tasking for portable toilets required that 162 be provided to Parkville, MO and vicinity and the necessary servicing contracted.

Several modifications were made to the water missions diverting shipments from one locale to another to meet the requirements of communities with water shortages. Contracting procedures to identify additional sources to meet the requirement for containerized water were successful. All of the above missions were completed and products or services were delivered on time.

2. Kansas Missions

The Disaster Field Office (DFO) for Kansas opened on 26 July in Topeka, Kansas. The first two ESF #3 missions for Kansas were received on 28 July. The missions were:

a. Provide 100 pumps of various sizes to the staging area in Topeka.

b. Provide 100 generators to the staging area in Topeka.

Subsequent missions included:

a. Provide 1,000 portable toilets to the staging area in Topeka.

b. Provide an additional 100 pumps.

c. Provide an additional 100 generators

d. Provide maintenance of pumps pre-positioned at the Topeka Mobilization Center at Forbes Field in Topeka. All actions necessary to pump floodwater out of the City of Elwood, Ks.

e. Provide maintenance of generators as needed. Blanket purchase agreement established with Prime Power personnel to purchase parts.

f. Provide temporary water and sewer system repairs in Elwood, Kansas.

All of the above missions were completed on schedule.

3. Nebraska and Iowa DFOs

The Nebraska DFO was staffed by a representative from the Missouri River Division and the Iowa DFO was staffed by a North Central Division representative. Liaison was maintained with both DFOs though no direct missions were received by the District from either DFO.

The Nebraska DFO requested an inspection of a potential Section 14 Streambank Erosion Project that had been damaged in previous floods and was critical to transportation. A request to provide pumps to Iowa was aborted when local officials determined a different size and type of pump was required.

4. Other Emergency Support Functions (ESF) and Agencies Supported by ESF #3

The Corps ESF #3 representative provided technical support to ESF #5 and other agencies regarding river stages, weather forecasts, and Corps flood fighting operations in the States of Missouri and Kansas. Data on levees was crucial to numerous agencies and ESFs that were providing emergency response to communities along the river.

## VIII. Levee Performance

### A. Corps Projects

1. Levee Design Performance

Table 17 is a list of the Federal levees along the Kansas and Missouri Rivers and shows the design discharge for the levees, the actual peak stage and discharge for the 1993 Flood, and the previous maximum stage and discharge. The table also lists the distance between the top of levee and the river when the river was at its peak stage in 1993 (remaining freeboard). Note that although the design discharge was exceeded at several levees, the levees were not overtopped. This occurred because the levees were designed with 2 to 5 feet of freeboard above the elevation required to provide protection at the design discharge. This freeboard prevented the levees from being overtopped even when the discharge was higher than the design discharge. Plates 126 thru 132 show the Federal levee project maps and depict the areas which are protected by those levees.

The Brush Creek Flood Control Project is not in the table below because it is still under construction. However, it deserves mention because the partially completed project provided enough reduction in flood heights during a severe storm on 10 July 1993 so that major damage did not occur. It is estimated that the flood height reduction prevented more damages than what the project will cost to construct.

# Table 17
# Corps Levee Design Performance

| Levee | Design Discharge (cfs) | Remaining Freeboard at 1993 Peak Discharge | 1993 Peak Discharge (cfs) | 1993 Peak Stage (Feet) | Previous Record Peak Discharge (cfs) | Previous Record Stage (Feet) |
|---|---|---|---|---|---|---|
| Missouri River Levees | | | | | | |
| R-512-513<br>Rulo, NE<br>River Mile 495 | 309,000 | 5 | 289,000<br>7/24/93 | 25.37 | 358,000[1]<br>04/1952 | 25.6 |
| L-504<br>Kimsey-Holly Creek, MO<br>River Mile 485 | 319,000 | 1 | | | | |
| R-500<br>Iowa Point, KS<br>River Miles 480-485 | 319,000 | Levee Overtopped | | | | |
| L-497<br>Forest City, MO<br>River Miles 475-483 | 319,000 | 1 | | | | |
| L-488<br>Forbes, MO<br>River Miles 465-475 | 322,000 | Levee Overtopped | | | | |
| R-482<br>Nodaway, MO<br>River Miles 458-468 | 325,000 | Levee Overtopped | | | | |
| L-476<br>Amazonia, MO<br>River Miles 454.5-460 | 325,000 | 3 | | | | |
| R-471-460<br>Elwood, KS<br>River Miles 441-456 | 325,000 | Levee Overtopped | 335,000<br>07/26/93 | 32.07 | 397,000[1]<br>04/1952<br>207,000[2]<br>05/1987 | 26.82[1]<br><br>23.83[2] |
| L-455<br>South of St. Joseph, MO<br>River Miles 437.5-446.5 | 325,000 | 0.1 | 335,000<br>07/26/93 | 32.07 | 397,000[1]<br>07/1952<br>207,000[2]<br>05/1987 | 26.82[1]<br><br>23.83[2] |
| L-448-443<br>Halls, MO<br>River Miles 429-437.5 | 325,000 | Levee Overtopped | | | | |

## Table 17
## Corps Levee Design Performance

| Levee | Design Discharge (cfs) | Remaining Freeboard at 1993 Peak Discharge | 1993 Peak Discharge (cfs) | 1993 Peak Stage (Feet) | Previous Record Peak Discharge (cfs) | Previous Record Stage (Feet) |
|---|---|---|---|---|---|---|
| R-440<br>Doniphan, KS<br>River Miles 425-432 | 429,000 | 7.5 | | | | |
| L-408<br>Rushville, MO<br>River Miles 392-402 | 270,000 | Levee Overtopped | | | | |
| L-400<br>Waldron, MO<br>River Miles 385-392 | 348,000 | Levee Overtopped | 541,000<br>07/27/93 | 48.87 | 625,000[1], [3]<br>06/1844<br>313,000[2]<br>09/73 | 38.0[1]<br>28.86[2] |
| R-351<br>Atherton, MO<br>River Miles 340-350 | 436,000 | 1 | | | | |
| L-246<br>Brunswick, MO<br>River Miles 239-250 | 400,000 | Levee Overtopped | 755,000<br>07/29/93 | 37.10 | 710,000[1]<br>06/1844<br>334,000[2]<br>10/1986 | 32.82[1]<br>31.85[2] |
| Chariton River<br>Glasgow, MO<br>River Miles 227.5-239 | 476,000 | Levee Overtopped | 755,000<br>07/29/93 | 37.10 | 710,000[1]<br>06/1844<br>334,000[2]<br>10/1986 | 32.82[1]<br>31.85[2] |
| New Haven<br>New Haven, MO<br>River Miles 82-82.5 | 529,000 | 1.5 | 755,000<br>07/31/93 | 37.10 | 892,000[1]<br>06/1844<br>549,000[2]<br>10/1986 | 35.50[1]<br>35.79[2] |
| **Kansas Citys Levees** | | | | | | |
| Argentine | 390,000 cfs on the Kansas River coincident with an upper Missouri River flow of 220,000 cfs. | 8.3 | 170,000<br>Kansas River<br>07/27/93<br>335,000<br>Missouri River<br>07/26/93 | 26.91<br>Kansas River | 510,000[1]<br>07/1951<br>146,000[2]<br>10/1973<br>(Kansas River) | 37.3[1]<br>27.54[2] |
| Armordale | 390,000 cfs on the Kansas River coincident with an upper Missouri River flow of 220,000 cfs. | 1.5 | 170,000<br>Kansas River<br>07/27/93<br>335,000<br>Missouri River<br>07/26/93 | 26.91<br>Kansas River | 510,000[1]<br>07/1951<br>146,000[2]<br>10/1973<br>(Kansas River) | 37.3[1]<br>27.54[2] |

# Table 17
## Corps Levee Design Performance

| Levee | Design Discharge (cfs) | Remaining Freeboard at 1993 Peak Discharge | 1993 Peak Discharge (cfs) | 1993 Peak Stage (Feet) | Previous Record Peak Discharge (cfs) | Previous Record Stage (Feet) |
|---|---|---|---|---|---|---|
| Central Industrial District, KS | 390,000 cfs on the Kansas River coincident with an upper Missouri River flow of 220,000 cfs. | 1.5 | 170,000 Kansas River 07/27/93 335,000 Missouri River 07/26/93 | 26.91 Kansas River | 510,000[1] 07/1951 146,000[2] 10/1973 (Kansas River) | 37.3[1] 27.54[2] |
| Central Industrial District, MO | 540,000 | 2.2 | 541,000 07/27/93 | 48.87 | 625,000[1, 3] 06/1844 313,000[2] 09/73 | 38.0[1] 28.86[2] |
| Lower Fairfax | 390,000 cfs on the Kansas River coincident with an upper Missouri River flow of 220,000 cfs | 2.5 | 170,000 Kansas River 07/27/93 335,000 Missouri River 07/26/93 | 26.91 Kansas River | 510,000[1] 07/1951 146,000[2] 10/1973 (Kansas River) | 37.3[1] 27.54[2] |
| Fairfax Jersey Creek Unit | 460,000 (above mouth of Kansas River) 540,000 (below mouth of Kansas River) | 3.3 | 335,000 07/26/93 (above mouth of Kansas River) 541,000 (below mouth of Kansas River) 07/27/93 | 32.07 (above mouth of Kansas R.) 48.87 (below mouth of Kansas R.) | 397,000[1] 07/1952 207,000[2] 05/1987 625,000[1, 3] 06/1844 313,000[2] 09/73 | 26.82[1] 23.83[2] 38.0[1] 28.86[2] |
| North Kansas City | 540,000 | 3.3 | 541,000 07/27/93 | 48.87 | 625,000[1, 3] 06/1844 313,000[2] 09/73 | 38.0[1] 28.86[2] |
| Northeast (East Bottoms) | 540,000 | 4.1 | 541,000 07/27/93 | 48.87 | 625,000[1, 3] 06/1844 313,000[2] 09/73 | 38.0[1] 28.86[2] |
| Birmingham | 540,000 | 4.5 | 541,000 07/27/93 | 48.87 | 625,000[1, 3] 06/1844 313,000[2] 09/73 | 38.0[1] 28.86[2] |
| **Kansas River Levees** | | | | | | |
| Manhattan | 220,000 | 3.1 | 199,000 07/26/93 | 27.33 | 400,000[1] 07/1951 72,900[2] 10/1973 | 30.56[1] 18.70[2] |

**Table 17**
**Corps Levee Design Performance**

| Levee | Design Discharge (cfs) | Remaining Freeboard at 1993 Peak Discharge | 1993 Peak Discharge (cfs) | 1993 Peak Stage (Feet) | Previous Record Peak Discharge (cfs) | Previous Record Stage (Feet) |
|---|---|---|---|---|---|---|
| Topeka | 314,000 | 4.7 | 170,000<br>07/25/93 | 34.9 | 469,000[1]<br>07/1951<br>130,000[2]<br>10/1973 | 40.80[1]<br><br>27.29[2] |
| Lawrence | 295,000 | 3.7 | 190,000<br>07/27/93 | 24.65 | 483,000[1]<br>07/1951<br>140,000[2]<br>10/1973 | 30.23[1]<br><br>22.73[2] |

[1]Before regulation.
[2]After regulation.
[3]Estimated

## 2. Levee Structural Performance

The record breaking high waters that persisted throughout the summer of 1993 significantly impacted the flood control levee structures in the District. Many of the District projects were tested for conditions equal to or greater than for which they were designed. During the flood fighting effort, District personnel observed many miles of the Missouri and Kansas levee units.

Without exception, all of the levee units performed as designed. As may be expected, serious seepage did occur landward of a number of the levees and sand boils were observed landward of five of the units; however, with the diligence of the sponsors' construction of ring dikes around the sand boils closest to the levees, the seepage did not cause any major loss of the levee integrity. However, there was great loss to crops due to the heavy seepage flows and ponding of interior runoff on some of the MRLS units which were not overtopped.

Six of the MRLS units were substantially overtopped resulting in four of them being completely breached by erosion of the levee embankment by overtopping scour. Three other units were overtopped with minor flows. Many of the breaches and serious scour areas occurred where riverside ramps were constructed perpendicular to the levee alignment and the heavy vegetation along the foreshore area restricted overbank conveyance of discharges.

Four of the units incurred levee sloughing. All of the sloughing instances probably occurred under a drawdown situation. However, there is a possibility that one might have occurred under a submerged toe condition.

Sinkholes caused by pipe joint leakage and subsequent piping of the adjacent soils were observed at six of the units. The most serious of these occurred on the North Kansas City Unit, Airport Section, Kansas City, Missouri and the Fairfax Jersey Creek Unit, Kansas City, Kansas. A number of sinkholes occurred landward of the Fairfax Unit with the worst of them being located at the Kansas City, Kansas Board of Public Utilities Plant immediately adjacent to the floodwall. In addition, there was a major sinkhole discovered in the riverside toe of the Fairfax levee embankment after the river flows had subsided to well below the crest. The first of the North Kansas City sinkholes occurred at the south pumping plant during the initial high water in May and caused settlement of the pumping plant resulting in total shutdown of the plant. The July flood occurred before the repairs could be completed, causing the city and the District to work closely together to intercept and pump the interior and relief well flows from this plant during the record high July flood. Like the Fairfax Unit, additional sinkholes occurred landward of the North Kansas City Airport Section during the July flood. The most threatening of these occurred near the North Pumping Plant, requiring the city to stop pumping through the plant. Since both pumping plants were inoperable it was necessary to operate pumps at 35 different pumping locations to handle all of the interior drainage and relief well discharges from 45 wells during the July flood. The pump discharges caused a loss of approximately 3,100 cubic yards of levee slope protection as the flood flows receded.

Not only did the levee overtopping, discussed above, cause some major scour holes, but there were an additional 10 units that incurred riverward scour holes with some of them occurring within the toes of the levee embankments.

There were a number of units that suffered erosion and loss of embankment and surfacing materials due to surface scour. Table 18 is a summary of the flood damage to Federal levees.

## Table 18
## Impacts to Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| **Missouri River Levees** | | | | |
| R512-R513<br>Rulo, NE | 7,151 acres cropland | * ramp damage | * 40 CY crushed gravel | |
| Kimsey-Holly Creek NW of St. Joseph, MO | cropland, railroads, state highway | * slope erosion<br>* ramp damage | * 115 CY random fill<br>* 15 CY crushed gravel | |
| R500<br>Troy, KS | 1,515 acres agricultural land | * levee overtopped<br>* slope erosion<br>* scour holes | * 1,124 CY impervious fill<br>* 6,700 CY random fill<br>* 1,018 sq yards erosion protection | erosion protection requires 17.5 acres seed & 2.52 acres mulch |
| R497<br>Forest City, MO | 6,800 acres cropland & a portion of Forest City | * ramp damage<br>* foundation piping & sand boils<br>* scour holes | * 43,600 CY impervious fill<br>* 31,300 CY random fill<br>* 7,400 CY rock fill | |
| L488<br>Forbes, MO | 8,365 acres of agricultural & timberland | * levee overtopped<br>* scour holes<br>* ramp damage | * 404 CY random fill<br>* 740 CY gravel | |
| R482<br>Nodaway, MO | 4,700 acres agricultural land | * levee overtopped<br>* scour holes | * 38,768 CY impervious fill<br>* 53,018 CY random fill<br>* seeding & mulching | |
| L476<br>Amazonia, MO | 6,000 acres including cropland, farms, railroads & town of Amazonia | * slope erosion/sloughing<br>* scour holes<br>* ramp damage | * 1,557 CY impervious fill<br>* 2,135 CY random fill<br>* 24 CY crushed aggregate | |
| R471-R460<br>Elwood & Wathena, KS | the City of Elwood, KS & 10,817 acres farm land | * levee overtopped/breached<br>* crest eroded<br>* scour holes, slope erosion<br>* drainage structures | * 3,074 CY random fill<br>* 37,006 CY impervious fill<br>* 450 ton crushed rock | dredge material may be used to fill scour holes to original elevation |
| L455<br>South of St. Joe | 7,519 acres including residential, agricultural & recreational land | * drainage structures damaged<br>* crest rutted/missing gravel<br>* scour holes/sink holes<br>* slope erosion/ramp damage<br>* pumps at stations | * 520 CY impervious fill<br>* 24 CY random fill<br>* 148 CY crushed gravel<br>* pipe & pumps repairs | |

## Table 18
## Impacts to Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| L448-L443<br>Forbes, KS | 18,080 acres including croplands, farms, railroads & state highway | * levee overtopped<br>* slope sloughing<br>* ramp damage | * 370 CY impervious fill<br>* 51 CY random fill<br>* 13 CY crushed gravel | |
| R440<br>Doniphan, KS | 4140 acres farm land | see remarks | see remarks | No assistance required, minor damage covered under O&M |
| L408<br>Rushville, MO | 7494 acres agricultural land, 2101 acres non-agricultural land | * levee overtopped<br>* slope erosion/ramp damage | * 15 CY impervious fill<br>* 225 CY random fill<br>* 40 CY crushed rock | |
| L400<br>Waldron, MO | the City of Waldron, MO & 3,860 acres farmland | * levee overtopped/breached<br>* slope/ramp erosion<br>* crest eroded/rutted<br>* scour holes/sand boils<br>* levee foundation piping<br>* railroad embankment damaged | * 100,630 CY impervious fill<br>* 270,200 CY random fill<br>* 990 CY crushed gravel<br>* 10,235 CY rock fill<br>* 650 ton aggregate | |
| R351 Section 1<br>Atherton, MO<br>R351 Section 2<br>Atherton, MO | the City of Atherton, MO railroads & agricultural lands, water & sewage plt | * slope erosion<br>* scour holes/sand boils<br>* ramp damage* crown rutting<br>* channel slope erosion<br>* erosion at drainage structures | * 4,535 CY rock fill/41 CY gravel<br>* 15,204 CY random fill<br>* 5,764 CY impervious fill* 9,105 tons rock fill<br>* 1,227 CY random fill | |
| L246<br>Brunswick, MO | agricultural lands | * levee overtopped/breached<br>* crown erosion<br>* slope erosion/scour holes | * 387,800 CY impervious fill<br>* 647,700 CY random fill<br>* 24,700 CY subsurface<br>* 435 acres seeding & mulching | |
| Chariton River<br>Glasgow, MO | agricultural lands | * levee overtopped/breached<br>* crown erosion<br>* scour holes/slope erosion<br>* piping/sand boils | * 833,746 CY impervious fill<br>* 569,947 CY random fill<br>* 7,597 CY road surfacing<br>* 24,648 CY quarry run rock<br>* 78 acres seeding<br>* 1,100 LF road relocation | |
| New Haven<br>Franklin County, MO | 7 blocks of business & residential property | see remarks | see remarks | No assistance required, minor damage repaired under O&M |

## Table 18
## Impacts to Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Kansas Citys Flood Protection Projects | | | | |
| Argentine Wyandotte County, KS | 2,031 acres industrial property, railyards & business | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Armourdale left bank Kansas River Kansas City, KS | 2,000 acres including industrial property, rail yards & businesses | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| CID, Missouri confluence of KS & MO Kansas City, MO | 732 acres of highly industrialized property | * displaced riprap<br>* scour of access roads<br>* road embankment eroded | * 416 CY riprap<br>* 15 CY random fill | |
| CID, Kansas Kansas City, MO | 360 acres of highly industrialized property | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Lower Fairfax Kansas City, MO | 2,036 acres including water & light plants, rail yards & industrial area | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Fairfax-Jersey Creek Kansas City, MO | same as above | * sink holes<br>* tieback levee sloughed<br>* gatewell manhole damaged | * 15,800 CY impervious fill<br>* 4,500 CY rock fill<br>* site work at pumping station (see remarks) | * 12,400 CY excavation<br>* 2,000 LF pilot hole<br>* 2 dewatering wells |
| N Kansas City Airport Sec | an airport, rail yards & numerous businesses | * sink holes including pump plant<br>* slope erosion/displaced riprap<br>* damaged manholes/scour hole | * 3,100 CY riprap/1400 CY fltr bs<br>* 16,400 CY random fill<br>* 6,700 CY impervious fill | |
| Birmingham | 5,000 acres | * displaced riprap<br>* ramp damage | * 207 CY rock | |
| Topeka, KS Units | | | | |
| North Topeka Unit | North Topeka business district | * landward sinkhole | see remarks | No assistance required, minor damage repaired under O&M |

## Table 18
## Impacts to Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Soldier Creek Unit | industrial & commercial properties, airport, sewage treatment plant | * slope erosion & slumping<br>* channel erosion | * 410 CY impervious fill<br>* 840 CY excav/430 CY RK fill<br>* 70 CY bedding material | |
| Topeka Waterworks | residential & commercial properties | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Oakland Unit | residential & commercial properties, airport, sewage treatment plant | * scour holes | * 4,450 CY impervious fill<br>* 6,200 CY random fill | |
| Auburndale Unit | residential & commercial properties | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| South Topeka Unit | 275 acres of highly developed land including railroads & industry | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| **Other Kansas/Nebraska Levees** | | | | |
| Indianola, NE | the city of Indianola, NE | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Bartley, NE | the city of Bartley, NE | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Seward, NE | the city of Seward, NE | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Fairbury, NE | the city of Fairbury, NE & 65 acres farmland | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Barnard, NE | the city of Barnard, NE | see remarks | see remarks | No assistance required, minor damage repaired under O&M |

## Table 18
## Impacts to Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Salina, KS | a portion of the City of Salina, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Gypsum, KS | the City of Gypsum, KS & 460 acres farmland | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Abilene, KS | business & industrial districts of the City of Abilene, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Elk Creek-Clyde, KS | the City of Clyde, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Frankfort, KS | the City of Frankfort, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Manhattan, KS Riley & Pottowatomie Counties | the City of Manhattan, KS (1,330 acres) | * ramp damage | * 44 CY gravel for resurfacing | |
| Stonehouse Creek, KS | the City of Williamstown, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Lawrence, KS | 8,920 acres including 500 homes, 60 businesses & an airport | * scour holes<br>* sinkhole | * 7,800 CY impervious fill | |
| Ottawa, KS | the City of Ottawa, KS | see remarks | see remarks | No assistance required, minor damage repaired under O&M |
| Osawatomie, KS | 450 acres including the City of Osawatomie, KS | * slope erosion<br>* scour holes<br>* piping/sink holes | * 90 CY riprap<br>* 150 sq yards jute mesh | |

## B. Non-Federal Projects

The intensity of rainfall yielded gage readings on the Missouri River that exceeded all previous floods of records from Brownsville, Nebraska to the mouth. This resulted in breaching of approximately 99 percent of all non-Federal levees along this 535 mile segment of the Missouri River.

Failures occurred by breaching, overtopping, wavewash, sidewash, and topwash. Millions of sandbags were used to try to prevent overtopping, sandboils and other failures. Photograph 10 shows a non-Federal levee about to fail. Many deep scour holes were formed in farmlands and huge quantities of sand were deposited, up to 8-10 feet deep at many locations. Table 19 is a summary of the flood damages at each non-Federal levee on the Missouri River. Those listed as ineligible for PL 84-99 assistance were not enrolled in the PL 84-99 program. Most of the non-Federal levees on streams other than the Missouri River were not eligible for the P.L. 84-99 Program. However, there were a few instances when the owner refused assistance, the levee was inactive due to poor maintenance, or the repair cost was not economically justified.

**Table 19**
**Impacts to Non-Federal Levees**

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| **Missouri River Levees** | | | | |
| Union Township LD<br>river mile 512 | 1,500 acres<br>2 structures | * levee overtopped<br>* 6 breaches | * 35,407 CY fill | |
| Holt County DD #10<br>river mile 492 | 13,000 acres | * levee overtopped | * 153,080 CY fill | |
| Holt County<br>LD # 9<br>river mile 490 | 8,640 acres<br>175 structures | * levee overtopped<br>* 14 breaches | * 115,374 CY fill | |
| Lowell-Kelly<br>river mile 489.8 | | | | ineligible for<br>PL 84-99 assistance |
| Canon Levee<br>DD of Holt County<br>river mile 483 | 2,685 acres<br>50 structures | * levee overtopped<br>* 10 breaches | * 7,662 CY fill | |
| Earl Cole (Buffalo<br>Hollow)<br>river mile 477.8 | | | | ineligible for<br>PL 84-99 assistance |
| Kuebler-Miller<br>river mile 437 | | | | ineligible for<br>PL 84-99 assistance |
| Bean Lake Levee<br>LD river mile 418.2 | 6,000 acres | * levee overtopped<br>* breached | * 21,151 CY fill | |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Rushville-Sugar Lake river mile 418 | 140,000 acres 1,500 structures | * levee overtopped * breached | * 323,570 CY fill | |
| Millard-Overton river mile 417 | 360 acres | | | ineligible for PL 84-99 assistance |
| POHL river mile 410 | 650 acres | * levee overtopped * breached | * 13,727 CY fill | |
| Wolcott DD river mile 381.2 | | | | ineligible for PL 84-99 assistance |
| Kansas Dept of Corrections river mile 388.1 | 3,200 acres | * levee overtopped * breached | * 163,170 CY fill | |
| Riverside-Quindaro Bend river mile 375 | | | | ineligible for PL 84-99 assistance |
| Riverside MRK river mile 374 | | | | ineligible for PL 84-99 assistance |
| Fort Meyer river mile 350 | 1,800 acres 77 structures | * levee overtopped * breached | * none required | |
| Crooked River river mile 348 | | | | ineligible for PL 84-99 assistance |
| C.W. Reasch river mile 347.8 | | | | ineligible for PL 84-99 assistance |
| Egypt river mile 337 | 2,511 acres 58 structures | | | inactive status due to poor maintenance |
| Stokes river mile 335 | 2,511 acres 40 structures | | | inactive status due to poor maintenance |
| Boggess river mile 334.2 | | | | |
| Robertson Levee river mile 334 | 2,511 acres 40 structures | | | inactive status due to poor maintenance |
| Yates Levee river mile 329 | | | | ineligible for PL 84-99 assistance |
| Remley (Reasch) river mile 328.3 | | | | ineligible for PL 84-99 assistance |
| Lloyd river mile 326.4 | | | | ineligible for PL 84-99 assistance |
| Waterloo DA river mile 326 | | | | ineligible for PL 84-99 assistance |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Jackson (Reasch) river mile 326 | | | | ineligible for PL 84-99 assistance |
| Lafayette County LD #1 river mile 323.9 | | | | ineligible for PL 84-99 assistance |
| Sunshine river mile 318 | | | | ineligible for PL 84-99 assistance |
| Hicks-Burnett river mile 318 | | | | ineligible for PL 84-99 assistance |
| Ray County LD river mile 318 | | | | ineligible for PL 84-99 assistance |
| Willow Creek #5 river mile 316 | | | | ineligible for PL 84-99 assistance |
| Hamilton (MRK) river mile 314 | | | | ineligible for PL 84-99 assistance |
| Noroborne Land DD river mile 314 | | | | ineligible for PL 84-99 assistance |
| Henderson (MRK) river mile 313.8 | | | | ineligible for PL 84-99 assistance |
| Ray County river mile 313.8 | | | | ineligible for PL 84-99 assistance |
| Oak Grove (Ray County # 10) river mile 312 | | | | ineligible for PL 84-99 assistance |
| Buchanan river mile 310 | | | | ineligible for PL 84-99 assistance |
| Kallenbergen river mile 308.2 | | | | ineligible for PL 84-99 assistance |
| Ray & Carrol LD #2 river mile 307 | | | | ineligible for PL 84-99 assistance |
| Miles Point DD river mile 304.2 | 845 acres<br>3 homes | * levee overtopped<br>* breached | * 18,810 CY fill | |
| Cherry Valley Land Devlpmt river mile 303 | | | | ineligible for PL 84-99 assistance |
| Baltimore Land Development river mile 299.8 | | | | ineligible for PL 84-99 assistance |
| Baltimore Island river mile 299.2 | 1,500 acres | | | ineligible for PL 84-99 assistance |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Hodge Bottom/Boyd Howerton river mile 296 | 1,100 acres | * levee overtopped * breached | * 60,935 CY fill | |
| Sugar Tree Bottom LD river mile 288 | 13,000 acres 140 structures | * levee overtopped * breached | * 350,970 CY fill | |
| Wakenda LD #1 river mile 280 | 29,650 acres 315 structures | * levee overtopped * breached | * 3,545 CY fill | |
| Farmers Drainage & Levee Dist river mile 270 | 13,991 acres 776 structures | * levee overtopped * breached | * 70,670 CY fill | |
| Whiterock Landowner Ass'n river mile 265 | | | | ineligible for PL 84-99 assistance |
| Saline LaFayette river mile 263 | 14,145 acres 4 structures | * levee overtopped * breached | * 430,371 CY fill | |
| Carr-Sal river mile 263 | | | | ineligible for PL 84-99 assistance |
| DeWitt DD LD Sections 1 & 2 river mile 255 | 3,500 acres | * levee overtopped * breached | * 19,674 CY fill | |
| MI-DE LD river mile 252 | 3,600 acres 15 structures | * levee overtopped * breached | * 153,710 CY fill | |
| Brunswick Levee LD river mile 250 | 3,700 acres | * levee overtopped * breached | * 127,646 CY fill | |
| Saline County Levee LD #2 river mile 248 | 3,200 acres | * levee overtopped * breached | * 276,454 CY fill | |
| Rhoades Island Levee river mile 237 | 1,300 acres | * levee overtopped * breached | | BCR < 1 |
| Cambridge Levee LD river mile 231.5 | 3,000 acres | * levee overtopped * breached | | BCR < 1 |
| Northeastern Saline LD river mile 227 | 836 acres | * levee overtopped * breached | * 89,332 CY fill | |
| Howard County Levee LD #6 river mile 222.5 | 416 acres | * levee overtopped * breached | * 15,344 CY fill | |
| Glasgow Levee Saline City levee Ass'n river mile 222.1 | 6,860 acres | * levee overtopped * breached | * 334,025 CY fill | |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Thompson Levee LD<br>river mile 213.8 | 1,000 acres | * levee overtopped<br>* breached | | BCR < 1 |
| Howard County<br>LD #5<br>river mile 213.7 | 1,740 acres | * levee overtopped<br>* breached | | BCR < 1 |
| Saline County<br>LD #1<br>river mile 213 | 740 acres | * levee overtopped<br>* breached | | BCR < 1 |
| Howard County<br>DD #3<br>river mile 212 | 5,052 acres<br>34 structures | * levee overtopped<br>* breached | * 252,874 CY fill | |
| Linneman-Weekly<br>Levee<br>river mile 204 | 1,000 acres | * levee overtopped<br>* breached | * 56,270 CY fill | |
| Howard County<br>LD #2<br>river mile 197.8 | 8,300 acres<br>47 structures | * levee overtopped<br>* breached | * 507,747 CY fill | |
| Howard County<br>LD #4 Section 1<br>river mile 194 | 5,000 acres | * levee overtopped<br>* breached | * 250,751 CY fill | |
| Merna-Overton<br>Levee Sec 2<br>river mile 189 | 400 acres | * levee overtopped<br>* breached | | poor maintenance |
| Merna-Overton<br>Levee Inc Sec 1<br>river mile 189 | 450 acres | * levee overtopped<br>* breached | | poor maintenance |
| Lyle<br>Howard County<br>Comm<br>river mile 187 | 275 acres | * levee overtopped<br>* breached | * 31,599 CY fill | |
| Bonne Femme<br>LD #1river mile 187 | 5,500 acres<br>35 structures | * levee overtopped<br>* breached | * 305,053 CY fill | |
| Merna-Overton<br>Levee Inc Sec 3<br>river mile 185 | 500 acres | * levee overtopped<br>* breached | | poor maintenance |
| Fayette Land Co<br>river mile 182 | | | | ineligible for<br>PL 84-99 assistance |
| Overton-Wooldridge<br>river mile 180 | 8,300 acres | * levee overtopped<br>* breached | * 288,946 CY fill | |
| Ray Lloyd<br>river mile 178 | 200 acres | | | ineligible for<br>PL 84-99 assistance |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Plowboy Bend Levee<br>LD & DD<br>river mile 167.6 | 2,600 acres | * levee overtopped<br>* breached | * 552,540 CY fill | |
| Capital View<br>DD<br>river mile 159 | 1,751 acres<br>10 structures | * levee overtopped<br>* breached | * 203,539 CY fill | |
| Hartsburg<br>LD Sect 2<br>river mile 153.5 | 1,000 acres<br>75 structures | * levee overtopped<br>* breached | * 16,305 CY fill | |
| Prison Farm<br>LD<br>river mile 152 | 1,300 acres | * levee overtopped<br>* breached | * 68,173 CY fill | |
| Hartsburg<br>LD Sect 1<br>river mile 151 | 1,900 acres<br>16 structures | * levee overtopped<br>* breached | *276,530 CY fill | |
| Hartsburg Levee<br>LD Sect 3<br>river mile 151 | 1,600 acres<br>8 structures | * levee overtopped<br>* breached | * 52,998 CY fill | |
| Cole Junction LD<br>river mile 146 | 2,600 acres | * levee overtopped<br>* breached | * 536,036 CY fill | BCR < 1 |
| Prison Farm<br>river mile 145 | 1,300 acres<br>15 structures | * levee overtopped<br>* breached | * 182,629 CY fill | |
| Cedar City LD DD<br>river mile 140 | Airport<br>4,100 acres<br>400 structures | * levee overtopped<br>* 26 breaches | * 93,319 CY fill | |
| Rievaux DD<br>river mile 137 | 2,550 acres<br>24 structures | * levee overtopped<br>* breached | * 82,461 CY fill | |
| Wainwright LD<br>river mile 134 | 2,700 acres | * levee overtopped<br>* breached | * 47,839 CY fill | |
| Goser Levee LD<br>river mile 134 | 750 acres | * levee overtopped<br>* breached | | BCR < 1 |
| Jacobs LD<br>river mile 130 | 350 acres | * levee overtopped<br>* breached | * 33,517 CY fill | |
| Tebbetts LD<br>river mile 125.2 | 1,859 acres | * levee overtopped<br>* breached | * 50,622 CY fill | |
| Mokane Levee LD<br>Sec 2 river mile 121 | 918 acres<br>4 structures | * levee overtopped<br>* breached | * 16,129 CY fill | |
| Chamois LD Sect 1<br>river mile 121 | 80 acres<br>4 structures | * levee overtopped<br>* breached | * 4,243 CY fill | |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Chamois LD Sect 2<br>river mile 121 | 500 acres<br>4 structures | * levee overtopped<br>* breached | * 714 CY fill | |
| Steedman LD<br>river mile 115 | 2,200 acres | * levee overtopped<br>* breached | * 159,141 CY fill | |
| Morrison Lower<br>Bottom LD<br>river mile 110 | | * levee overtopped<br>* breached | * 21,215 CY fill | |
| A-1 Levee Ass'n<br>river mile 110 | 1,500 acres | * levee overtopped<br>* breached | * 1,213 CY fill | |
| Diermann LD<br>river mile 109 | 350 acres | * levee overtopped<br>* breached | | BCR < 1 |
| Island Levee<br>river mile 108.2 | | | | Inactive status |
| Rast Levee<br>river mile 108 | | | | Inactive status |
| Tri-County<br>LD Sect 2<br>river mile 92 | 5,900 acres<br>15 structures | * levee overtopped<br>* breached | * 223,210 CY fill | |
| Tri-County<br>LD Sect 1<br>river mile 92 | 7,200 acres<br>15 structures | * levee overtopped<br>* breached | * 338,574 CY fill | |
| Berger LD<br>river mile 83 | 8,460 acres<br>5 structures | * levee overtopped<br>* breached | * 424,414 CY fill | |
| New Haven<br>river mile 81 | 60 structures | | | damage covered by<br>O & M |
| Pinckey Peers<br>river mile 76 | 8,870 acres | * levee overtopped<br>* breached | * 218,413 CY fill | |
| Holtmeier<br>river mile 73 | 400 acres | * levee overtopped<br>* breached | * 18,089 CY fill | |
| Charrette Bottom<br>LD Sect 4<br>river mile 72 | 350 acres | * levee overtopped<br>* breached | * 1,560 CY fill | |
| St John LD<br>river mile 70 | 853 acres<br>1 structure | * levee overtopped<br>* breached | * 40,289 CY fill | |
| Tuque Creek<br>LD Sect 2<br>river mile 68 | 2,000 acres<br>2 structures | * levee overtopped<br>* breached | * 12,607 CY fill | |
| Dutzow Bottoms LD<br>river mile 66 | 2,950 acres<br>35 structures | * levee overtopped<br>* 15 breaches | * 95,821 CY fill | |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Miami LD #1<br>river mile 61 | 3,000 acres | * levee overtopped<br>* breached | * 192,216 CY fill | |
| Augusta Levee LD<br>river mile 57.3 | 6,700 acres | * levee overtopped<br>* breached | * 290,287 CY fill | |
| LaBadie Bottoms<br>LD river mile 55 | 2,400 acres | * levee overtopped<br>* breached | * 19,459 CY fill | |
| Darst Bottoms LD<br>Sect 2 river mile 51 | 3,500 acres | * levee overtopped<br>* breached | * 267,089 CY fill | |
| Darst Bottoms LD<br>Sect 1 river mile 51 | 3,500 acres | * levee overtopped<br>* breached | | poor maintenance |
| Missouri University<br>river mile 49 | | * levee overtopped<br>* breached | * 2,881 CY fill | |
| Monarch-<br>Chesterfield LD<br>river mile 41 | Airport<br>5,620 acres<br>350 structures | * levee overtopped<br>* breached | * 80,000 CY fill | Phase 1 |
| Monarch-<br>Chesterfield LD<br>river mile 41 | Airport<br>5,620 acres<br>350 structures | * levee overtopped<br>* breached | * 81,366 CY fill<br>*12,600 CY impervious fill<br>*11,025 T rock fill | Phase 2 |
| Grape-Bollin-<br>Schwartz<br>river mile 40.6 | | | | ineligible for<br>PL 84-99 assistance |
| Greens Bottom<br>LD #2 Sect 2<br>river mile 39 | 100 acres | * levee overtopped<br>* breached | * 21,8049 CY fill | |
| Greens Bottom<br>LD #2 Sect 1<br>river mile 34 | 3,000 acres<br>19 structures | * levee overtopped<br>* breached | * 1,476 CY fill | |
| Howard Bend LD<br>river mile 31 | 6,000 acres | * levee overtopped<br>* breached | * 82,850 CY fill | |
| Missouri Bottoms<br>LD river mile 23 | 2,700 acres<br>54 structures | * levee overtopped<br>* breached | * 143,310 CY fill | |
| Cora Island<br>river mile .3 | | * levee overtopped<br>* breached | * 43,885 CY fill | |
| Garden of Eden<br>Section 1<br>Grand River | 7,600 acres<br>25 homes<br>7 businesses | * levee overtopped<br>* breached | * 154,850 CY fill | |
| Garden of Eden<br>Section 2<br>Grand River | 3,500 acres<br>16 homes | * levee overtopped<br>* breached | * 191,190 CY fill | |

## Table 19
## Impacts to Non-Federal Levees

| Levee | Protected Area | Impact to Levee | Levee Repair Quantities | Remarks |
|---|---|---|---|---|
| Garden of Eden<br>Section 3<br>Grand River | 4,200 acres<br>25 homes | * levee overtopped<br>* breached | * 160,582 CY fill | |
| Little Tarkio DD<br>Sec. 1 & 2 Rt. Bk.<br>river mile 512 | 2,000 acres | * levee overtopped<br>* breached | * 11,568 CY fill | |
| Little Tarkio DD<br>Sec. 1 & 2 Lt. Bk.<br>river mile 512 | 700 acres | * levee overtopped<br>* breached | * 13,047 CY fill | |
| Little Tarkio DD<br>Sec. 3<br>river mile 512 | 2,100 acres | * levee overtopped<br>* breached | * 12,536 CY fill | |
| St. Alban's/Labadie<br>Bottoms<br>river mile 57.7 | 3,050 acres | * levee overtopped<br>* breached | * 233,074 CY fill | |
| Whitham Levee &<br>Drainage Dist.<br>Grand River | 6,000 acres<br>25 homes | * levee overtoppeed<br>* breached | * 10,200 CY fill | |

# IX. Navigation

## A. Interruption by Flood

By 2 July, river levels were above flood stages and rapidly rising on the Federal and non-Federal levees when the District recommended the U.S. Coast Guard close the river for navigation in stages from Brownsville, Nebraska at river mile 535 to the mouth. At least eight tows and more than 50 barges were stranded during the period when the river was closed. The river was opened in all reaches to navigation by 20 August.

Impacts to the navigation structures were substantial in that stone filled dikes and revetment structures were severely damaged in at least 45 locations and will have to be repaired or replaced. Side channel areas were also severely eroded which will allow potential future channel changes and/or create conditions for shoaling within the navigable channel. Approximately 21 percent of the navigation season was lost due to the flood and will be reflected in statistical data on tonnage from the Water Resources Support Center.

During the flood several barges broke loose from their moorings, but were stopped and secured several miles downstream. The former Corps of Engineers dredge, William S. Mitchell, listed on the National Register of Historical Places, broke loose from its mooring near the mouth of the Kaw River, struck two railroad bridges and three highway bridges before being caught and secured approximately three miles downstream. The dredge was severely damaged, but remained afloat. Photograph 11 is a picture of the damaged Dredge Mitchell.

## B. Recovery

Plans are underway to restore the damaged stone fill structures in areas where complete destruction or washout occurred. Restoration of other damaged structures is being evaluated and repairs are being accomplished in an orderly manner. Severe degradation of the river channel has occurred and a resurvey is underway. The blew hole evaluations and the effects on the navigation channel will also be reviewed.

# X. Flood Damage Description and Appraisal

## A. Flood Damage Description

Following is a description of flooding in some of the more severely affected areas of the District. Sources of the information, which is preliminary, include media accounts from throughout the District, data from other government agencies (e.g., FEMA, SCS, ASCS, USDA), and data from project information reports on levees repaired by the District under Public Law 84-99. Population figures are based on the 1990 census. The description begins at the upstream District boundary on the Missouri River.

1. Missouri River-Northwestern Missouri and Northeastern Kansas

This area was one of the most troublesome areas for Missouri River flooding, and the protection provided by the Missouri River Levee System (MRLS) in this area was mixed. Two of the three MRLS units near the Nebraska border successfully prevented damage estimated at $2.1 million to nearly 14,000 acres. These included unit R-513-512, just below Rulo, Nebraska, and L-497, below Big Lake, Missouri. The third unit, R-500, near Iowa Point, Kansas, was overtopped and failed. Further downstream in the general area of St. Joseph, three of four MRLS units were overtopped, including L-488, near Nodaway, Missouri; R-482, across the river from Forest City, Missouri; and R-471-460, at Elwood, Kansas. The L-476 unit at Amazonia, Missouri did hold, preventing damages estimated at $837,000 to more than 5,500 acres.

Virtually the entire town of Elwood, Kansas (Mo. river mile 448) was devastated by flooding from the Missouri River beginning 24 July when the R-471-460 Federal levee first overtopped and then failed. An estimated 450 homes and the entire business district in the town of 1,079 people were inundated with an average of six feet of flooding. Also flooded were the Rosencrans Memorial Airport, which serves St. Joseph, Missouri, and a Missouri Air National Guard base, both adjacent to the town. The Air Guard base suffered an estimated $16 million in damage, including several million dollars of losses to inundated aviation equipment. Other damages at the airport were estimated at more than $1 million.

The levee failure followed a period of intense rainfall in southeastern Nebraska, resulting in a total July rainfall of 20.7 inches, about 17 inches higher than the July average for the area.

One major, long-term impact of the flood was the closing of Sherwood Medical Company's plant, a key regional employer in the Elwood/St. Joseph area. Sherwood, which made sterile medical devices, suffered major damage from four feet of flooding in its plant after R-471-460 overtopped and breached. The company decided not to reopen the facility, causing the loss of 722 jobs. Sherwood is, at this writing, the largest company in Missouri to close permanently as a result of the 1993 flood.

Across the river, the City of St. Joseph (pop. 71,852) lost its water supply for nearly a week beginning 25 July. This resulted in significant disruption, including automatic closings and lost business for the more than 200 restaurants and taverns in the city. An industrial and agricultural portion of southwestern St. Joseph was spared damage when MRLS unit L-455 held, preventing damages of about $175.9 million to an area of more than 7,500 acres.

Just upstream of St. Joseph, the 50 residents of Nodaway (Mo. River mile 463, left bank) were flooded up to their rooftops by a combination of the Missouri and the Nodaway Rivers. Damage to homes and businesses was estimated at over a million dollars in Nodaway. Another tributary of the Missouri, the One Hundred and Two River, inundated Rosendale (pop. 186) with four to eight feet of water. About two dozen homes were damaged. Estimated damage to homes and businesses was over $800,000.

Two lake communities near the Buchanan/Platte Counties line, Sugar Lake (Mo. River mile 421, left bank) and Bean Lake (Mo. River mile 417, left bank), were flooded by the Missouri River when private levees protecting the area failed. About 100 homes at each of these lake communities were severely damaged. Residential damages at Sugar Lake were estimated by one regional council to be more than $1.5 million, along with $200,000 in commercial damages. In most cases, the homes were a total loss and buy-outs are planned. The regional council has estimated damage to a railroad in this area at $1.7 million, with an equal amount in losses from rerouting rail traffic. Over half a million dollars in losses also occurred due to rerouting from the closing of U.S. Highway 59, which was badly damaged. County road 241 was damaged so severely, and buried in so much sand, that it may not be reopened. Crops in this mostly rural part of the state sustained serious damage. Of the two MRLS units in this area, L-448-443, near Rushville on the Missouri side, held and prevented $1.9 million in damage to over 18,000 acres. R-440, just above Atchison on the Kansas side, also held, preventing over $700,000 in damage to more than 4,100 acres.

2. Missouri River-Upstream of Kansas City

Just upstream of Kansas City, Kansas, the town of Wolcott, Ks. (Mo. River mile 384, right bank) was flooded by Missouri River water when private levees protecting the area failed. About three dozen families in this unincorporated community suffered damage, with flood depths inside the homes reportedly reaching five to nine feet. This community is immediately downstream of MRLS units L-400 and L-408, near Farley and Waldron, Missouri. L-408 had minor damage and L-400 overtopped and breached. L-408 prevented $1,145,403 in damages. L-400 provided partial protection despite the damage it sustained, preventing an estimated $268,000 in damages.

Two communities on the north side of the Missouri River just upstream of downtown Kansas City, Parkville and Riverside, suffered flood damage unprecedented in their histories. Several blocks of Parkville's commercial district were inundated with up to seven feet of water. The city hall and post office were ruined inside and many small businesses were wiped out. Damage in Parkville was estimated at nearly $8 million. As in most other communities affected by Missouri River flooding, the water remained in the buildings for weeks. Photograph 12 is an aerial view of downtown Parkville, looking south across the Missouri River.

In Riverside, just downstream of Parkville, most of the business district was flooded with only the peaks of rooftops visible at the height of the flooding. The prior flood of record in 1951 caused only two to three feet of flooding in the same area. Riverside, in recent years, has developed a thriving industrial base, and most of these businesses were severely damaged. Damages in Riverside are estimated to have exceeded $100 million to more than 180 firms. Several businesses in both Parkville and Riverside opted to shut down permanently. The Red-X General Store, which generated more than a third of the city's annual revenue, has partially reopened as of March 1994. Although final flood damage estimates are not yet available, the damage total in Riverside was the second-highest of all Missouri communities. A proposed Federal levee which would protect Riverside, L-385, is authorized and awaits construction.

Also in this area, Interstate Highway 635 was damaged by a break of about 900 feet. An estimated 21,000 drivers use this portion of the highway each day. Repair costs were estimated at $1.5 million. Photograph 13 is looking west from Riverside toward Parkville. The L-385 Levee area and Interstate Highway 635 are in the background.

3. Kansas River Basin

Damage generally was not as severe along the Kansas River, which runs into the Missouri River at Kansas City, but there were exceptions. Riley County, which includes the regional trade and commercial center Manhattan, Kansas, was inundated by repeated rainstorms and by releases from Federal reservoirs which were necessitated by the storms. This area probably was the worst-damaged in the state after Elwood. Photograph 14 is an aerial view of flooding in Manhattan. The Federal local protection levee at Manhattan prevented damages of at least $12 million in the city. At Topeka, Kansas, the Federal levee system, consisting of the Oakland, North Topeka, South Topeka, and Auburndale units, successfully prevented damages of nearly $60 million to the city. The U.S. Highway 75 bridge over the Kansas River north of Topeka was washed out. The Federal local protection levee at Lawrence, Kansas, prevented at least $5 million in damages.

At least 17 towns along the Smoky Hill River basin (a major Kansas River tributary which includes the Saline and Solomon Rivers) incurred damage. Chief among these was Natoma, Kansas (pop. 500), which suffered flooding of two to three feet over the southern half of town, resulting in more than $1 million in damage. Other towns with damages estimated to exceed $50,000 included Junction City, Beverly, Tescott, Paradise, and Enterprise, all in Kansas.

Significant damage also occurred along two other major Kansas River tributaries, the Big Blue and the Republican Rivers. Estimated damages in the Big Blue River basin exceeded $3 million, much of which was account for in the towns of Staplehurst, Nebraska, where a major grain elevator operation sustained severe damage; Marysville, Kansas where a flash flood damaged several dozen homes; and Haddam, Kansas, which suffered more than $425,000 in damages from the Little Blue River. Damages in the Republican River basin exceeded $1 million, with damages occurring at Junction City (also flooded by the Smoky Hill River), Morgansville, Clifton, Vining, and Wakefield.

4. Kansas City Area

The Kansas City Federal levee system (comprised of the Argentine, Armourdale, C.I.D., Fairfax, North Kansas City, Northeast and Birmingham units), together with reservoir projects upstream along the Kansas and Missouri Rivers, were responsible for by far the greatest portion of flood damages prevented within the Kansas City District. All of these Federal levee units held, although several narrowly escaped overtopping by river crests. All of these levees sustained at least minor damage. An estimated $4.57 billion in losses was prevented by the Kansas City Federal levee system. Main stem reservoirs on the Missouri above Kansas City prevented an estimated $3.772 billion in damages, much of that at Kansas City. Photograph 15 is looking east across the Kansas River toward downtown Kansas City, Missouri. The Central Industrial District, shown between the river and downtown Kansas City, Missouri, was protected by the Federal levees. Photograph 17 is looking west upstream on the Missouri River. Note the mouth at the Kansas River in the upper left, the grain storage and petroleum tanks protected by the Fairfax levee, and the downtown airport on the right, protected by the North Kansas City levee.

In Kansas City, Kansas, several low-lying trailer courts and other homes near Kansas River mile 10 were damaged and many mobile homes were destroyed by flood waters from the river. An estimated 600 mobile homes and 200 other homes were affected. Damages to the city's utilities also reached several million dollars.

Kansas City, Missouri reported more than $15 million in damage to public infrastructure, although it must be emphasized that the damage would have been far worse in the absence of the flood control projects protecting the city. The Kemper Arena and the just-completed American Royal Building, two major public facilities in the city's old stockyards area, suffered about $2.5 million in water damage to flooring and electrical circuits from Turkey Creek overflows. The downtown airport had damages of nearly $3 million. Pollution control and public works facilities sustained an estimated $8 million in damage.

The most severe damage in Kansas City, Missouri, was the result of a Turkey Creek flash flood on 10 July. This flood was part of the same storm system that produced the Missouri River flooding of 1993, although it occurred earlier than the river flooding. The commercial area along Southwest Boulevard, which floods frequently and is the subject of a current Corps flood control feasibility study, suffered probably the worst flood in its history, with many businesses devastated by seven to twelve feet of water. Damages in the area, mostly commercial and industrial, were estimated to exceed $15 million. One death by drowning also occurred. Several businesses affected announced they will move or go out of business.

The city also largely escaped potentially serious flood damages from the Blue River. The lower part of the Corps' Blue River Channelization Project is essentially complete and successfully contained crests toward the mouth of the river. The Brush Creek Flood Control Project, under construction, provided enough reduction in flood heights so that damage did not occur in the upscale Country Club Plaza area, site of a devastating flood in 1977. It is estimated that the damages prevented along Brush Creek in 1993 exceeded the total cost of the project.

In the southern Kansas City metro area, damage also occurred along Indian Creek, except in the upstream portion of the creek where a Corps channelization project had been completed. A flash flood also damaged the Wabash Circle area of Olathe, Kansas, the suburban county seat of Johnson County in the southwestern portion of the metro area. About 35 homes were flooded by Mill Creek, a tributary of the Kansas River. A Corps flood control feasibility study of this area is underway.

5. Missouri River-Downstream of Kansas City

Several small Missouri communities on the eastern edge of the metro Kansas City area or just downstream of the area received major damage. In Clay County, Missouri City (Mo. River mile 344, left bank) had about 70 homes which were inundated by four to six feet of water from the river. The downtown commercial area and the grade school also were flooded. A Fishing River flash flood on the night of 11 August also caused severe damage in Excelsior Springs and Richmond. The flooding in Excelsior Springs reportedly put eight or more feet of water in most of the downtown commercial area, as well as damaging city bridges, parks, and historic buildings. Preliminary estimates of damage reached $12 million.

The town of Orrick (Mo. River mile 334, left bank), with a population of 935, suffered damage to more than 300 homes, about half of which were damaged severely. The flooring in the high school and grade school were ruined. Social workers in the area reported a proliferation of post-traumatic stress syndrome after the town had been flooded for several weeks. Across the river, Levasy (pop. 279) had about 20 homes with flood damages. Missouri Highway 13 was inundated and closed for weeks, cutting off access to Lexington, MO.

Featured widely on the national news was the town of Hardin (Mo. River mile 313, left bank), where a 180-year-old cemetery was flooded. More than 800 caskets and bodies washed away, and many were never recovered. The emotional distress which resulted for relatives and friends in the town of 598 merely compounded the physical stress felt from the town's flooding. More than 200 homes were flooded and the school's floor buckled. State highway 10 near Hardin was damaged when a hole about 47 feet deep was cut by the river. One drowning death occurred nearby, in Henrietta.

6. Grand River Basin

The Grand River's confluence with the Missouri is at Missouri River mile 250. Much of the Grand River floodplain flooded twice during the summer, and even three times in some cases. Most of this area is rural and reliable estimates of flood damages await a field survey. Crop damage was major in this region. Brunswick (pop. 1,074) was flooded by both the Missouri and the Grand. A one-half mile stretch of U.S. Highway 24 was damaged near Brunswick, with repair costs estimated at more than $1 million. Chillicothe (pop. 8,804) was flooded on the west side of town by the Grand. Preliminary estimates placed damage near $1 million. Thirty homes and 7 businesses were affected, including Churchill Truck Lines, one of the city's largest employers (which is now out of business).

Severe flooding struck Pattonsburg (pop. 414), apparently throughout most of the town, on 6 July and again on 24 July. Nearly 300 residences were damaged, as well as most of the commercial sector. Schools in the town sustained damage estimated at $500,000. Most buildings had three to six feet of water inside. Several businesses reported that they will not reopen, including the town's only grocery store. One cafe owner died during the flooding when he was electrocuted. In the wake of the flooding, plans are under consideration for relocating the town to higher ground. Daviess County, which includes Pattonsburg, expected costs to total $2 to $3 million for replacing three large truss bridges washed away by flooding on the Grand. Gallatin, Missouri (pop.

1,864) also sustained significant damage. Further upstream, Bethany (pop. 3,005) had about two dozen homes which were flooded by Big Creek, a major tributary of the Grand.

7. Missouri River-Central Missouri

The Missouri River flooding caused major damage to roads and levees near the town of Glasgow (Mo. River mile 227, left bank). The town itself had little damage, but two Federal levees, the Lower Chariton and L-246 units, sustained severe damage, with combined repair costs for the two units estimated at nearly $19 million. The Gateway Western Railroad suffered damages of nearly $3.5 million when two sections of trestle collapsed and many track sections were destroyed. Photograph 16 shows the railroad bridge washout. The closing of the Missouri River bridge in this area due to damage to state highway 240 caused an 80-mile detour for people who live on one side of the Missouri River and work on the other side. Downstream of Glasgow, New Franklin, Missouri (pop. 1,107), suffered damages estimated to exceed $4 million.

The state capitol, Jefferson City (Mo. River mile 146) was among the worst-damaged cities in Missouri, with estimated damages exceeding $15 million. The frequently flooded North Jefferson City area (formerly known as Cedar City), which is the subject of the L-142 flood control feasibility study currently in progress, was decimated. About 120 homes are expected to be bought out. Thirty-five buildings were completely washed away. One of the region's major employers, Asea, Brown, Boveri, Tool and Die Company, Inc., sustained several million dollars in damages. Photograph 18 shows flooding in the Jefferson City area. On the south side of the river, damage was also severe. The Renz Correctional Center, a part of the state's prison system, was essentially destroyed, with flood damages estimated at $8 million. It will not be rebuilt on that site. An unknown number of homes and businesses near downtown were flooded. U.S. Highway 54 was severely damaged in Jefferson City, resulting in the closing of the bridge over the Missouri. This effectively separated North Jefferson City from the capitol area and caused extremely long detours. Traffic rerouting costs in this area are undetermined but major. Just upstream of Jefferson City, the town of Hartsburg (Mo. River mile 155, left bank), population 130, was inundated by about four feet of water throughout most of the town. Several other small river towns just above Jefferson City also flooded.

8. Missouri River-Wine Country

Farmland between Jefferson City and St. Louis increasingly is being converted to the growing of grapes for wine production, although not necessarily in the river bottoms. Several of the leading wine-producing towns in the region were affected by the flood. In Hermann, Missouri (river mile 98, right bank), the most prosperous and picturesque town in the region, about 40 businesses and 100 homes were flooded by small Missouri River tributaries. Access to the town was cut off in all directions, resulting in large losses to businesses during the summer vacation season. One leading winery in the city reported a 60 percent drop in expected business during July. Photograph 19 shows flooding in Hermann. Across the river and just upstream, Rhineland (Mo. River mile 102, left bank) had more than $1 million in losses..

Further downstream, and just upstream from the metro St. Louis area, the town of Washington (Mo. River mile 69, right bank) sustained damage in some parts of town and was inconvenienced by the closing of the severely-damaged Highway 47 bridge over the Missouri. On the left bank, the area including the towns of Dutzow, Augusta, Defiance, and Marthasville (Mo. River mile 73 to 51, left bank) suffered substantial urban damage and the surrounding land sustained serious crop damage, including severe localized sand deposits on the crop land.

9. Missouri River-St. Louis area

Floodwaters receded in this area much later than elsewhere in the Kansas City District. There were two major damage areas on the Missouri River near St. Louis. Chesterfield (Mo. River mile 49) was the site of the worst damage, in economic terms, in the state. The area's industrial park contains at least 250 small businesses which were inundated by an average of eight feet of water when the private Monarch-Chesterfield levee protecting the area from the Missouri River failed. The Spirit of St. Louis Airport, the second-busiest airport in Missouri, also was in the flooded area. Damages to industry and transportation in the Chesterfield industrial district exceeded $200 million. An estimated 4,500 employees in the valley were out of work for several weeks. In addition, U.S. Highway 40/Interstate Highway 64 was closed because of inundation. The closing of this major west-side traffic artery produced reportedly the worst traffic jams in the history of St. Louis. Traffic rerouting losses in this area, when estimated, will be major. Photograph 20 shows flooding in the Monarch-Chesterfield industrial area.

The second major area of damage in the metro St. Louis area was in St. Charles County, which is on the left bank of the Missouri and the right bank of the Mississippi. Total damages in St. Charles County are estimated to exceed $300 million. Much of the damage occurred either in the County seat of St. Charles or in small towns located in the dual floodplain between the Mississippi and the Missouri. The towns of Portage des Sioux, Orchard Farm, and West Alton were covered with waters ranging from one to 20 feet. Early estimates indicated that up to 800 homes in the county might be uninhabitable. Buy-outs currently are planned for about 450 homes. A state Housing Development Commission official stated that, of the housing losses in Missouri, about one-fourth of the losses occurred in St. Charles County. The superintendent of one county school district estimated at the beginning of the school year that 1,000 of the 1,400 students in the district were homeless. Photograph 21 shows flooded areas in St. Charles County, Missouri.

## B. Total Damages Sustained

### 1. Crop damages

Many of the crop acres in the District floodplains suffered losses, due to the total or partial failure of 9 of the 15 units in the Federal Missouri River Levee System and virtually all of the non-Federal farm levees. More than 1.6 million crop acres are classified as failed due to the Flood of 1993, resulting in damages of $359 million. Table 20 summarizes flood-caused damages to crops in the District, based on information from SCS, ASCS, USDA, FEMA, and District files.

**Table 20**
**Crop Damages by State and Stream**

| River | State | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Missouri | | Kansas | | Iowa | | Nebraska | | | |
| | Acres Flooded (1,000) | Damage ($1,000) | Acres Flooded (1,000) | Damage ($1,000) | Acres Flooded (1,000) | Damage ($1,000) | Acres Flooded (1,000) | Damage ($1,000 ) | Acres Flooded (1,000) | Damage ($1,000) |
| Missouri | 641 | 160,360 | 34 | 8,589 | | | 4 | 1,011 | 679 | 169,960 |
| Kansas | | | 83 | 20,750 | | | | | 83 | 20,750 |
| Republican | | | 80 | 20,000 | | | 42 | 10,500 | 122 | 30,500 |
| Smoky Hill | | | 114 | 28,500 | | | | | 114 | 28,500 |
| Big Blue | | | 4 | 1,000 | | | 75 | 18,750 | 79 | 19,750 |
| Grand | 226 | 56,500 | | | 1 | 250 | | | 227 | 56,750 |
| Osage | 46 | 11,500 | | | | | | | 46 | 11,500 |
| Chariton | 8 | 2,000 | | | | | | | 8 | 2,000 |
| Nodaway | 49 | 12,250 | | | 13 | 3,250 | | | 62 | 15,500 |
| Platte | 17 | 4,250 | | | | | | | 17 | 4,250 |
| Total | 987 | 246,860 | 315 | 78,839 | 14 | 3,500 | 121 | 30,261 | 1,437 | 359,460 |

### 2. Urban Damages

Residential, commercial and industrial damages in urban areas total $661 million. The hardest-hit towns in the District were Chesterfield, Riverside, Jefferson City, St. Charles, West Alton, Portage des Sioux, and Kansas City in Missouri and Elwood, Manhattan, and Kansas City in Kansas. Other towns which were especially hard hit include Parkville, Bean Lake, Carrollton, New Franklin, St. Joseph, Excelsior Springs, Brunswick, Pattonsburg, Orrick, Hardin, Missouri City, and Hermann in Missouri, and

Wolcott and Natoma in Kansas. Table 21 summarizes estimated urban damages along each major stream.

**Table 21**
**Urban Damages**

| Urban Area | Damage ($1,000) | Urban Area | Damage ($1,000) |
|---|---|---|---|
| Missouri River | | Missouri City, MO | 968 |
| Rulo, NE | 175 | Orrick, MO | 1,529 |
| Big Lake, MO | 4,086 | Floyd, MO | 1 |
| Fortescue, MO | 124 | Levasy, MO | 116 |
| Craig, MO | 872 | Indep./Sugar Crk, MO | 1,992 |
| Nodaway, MO | 1,151 | Lexington, MO | 91 |
| Wathena, KS | 5,188 | Wellington, MO | 5 |
| White Cloud, KS | 30 | Waverly, MO | 12 |
| Elwood, KS | 92,305 | Henrietta, MO | 519 |
| St. Joseph, MO | 3,802 | Hardin, MO | 1,339 |
| Lake Contrary, MO | 105 | Norborne, MO | 13 |
| Atchison, KS | 875 | Carrollton, MO | 4,246 |
| Sugar Lake, MO | 1,893 | Wakenda, MO | 451 |
| Winthrop, MO | 537 | Brunswick, MO | 2,098 |
| Lewis & Clark Vil., MO | 1,462 | Petersburg, MO | 29 |
| Bean Lake, MO | 3,562 | Franklin, MO | 166 |
| Weston, MO (incl Iatan) | 166 | New Franklin, MO | 5,730 |
| Beverly, MO | 51 | Glasgow, MO | 9 |
| Leavenworth, MO | 461 | Rocheport, MO | 62 |
| Waldron, MO | 1,640 | Wooldridge, MO | 285 |
| Wolcott, KS | 2,796 | McBaine, MO | 420 |
| Parkville, MO | 7,511 | Boonville, MO | 192 |
| Riverside, MO | 109,511 | Lupus, MO | 297 |
| North Kansas City, MO | 150 | Sandy Hook, MO | 113 |
| Kansas City, MO | 4,000 | Wilton, MO | 53 |

## Table 21
## Urban Damages

| Urban Area | Damage ($1,000) | Urban Area | Damage ($1,000) |
|---|---|---|---|
| Hartsburg, MO | 615 | Defiance, Mattson, Augusta, MO | 476 |
| Easley, MO | 95 | West Alton, MO | 17,728 |
| Jefferson City, MO | 15,181 | Portage des Sioux, MO | 9,871 |
| Osage City, MO | 410 | OrchFarm, Blk Walnut, Boschertown, MO | 415 |
| Bonnots Mill, MO | 140 | Elm Point, MO | 6,628 |
| Chamois, MO | 1,147 | Total Missouri River | 590,958 |
| Portland, MO | 5 | Grand River | |
| Mokane, MO | 165 | Sumner, MO | 147 |
| Steedman, MO | 169 | Dalton, MO | 141 |
| Wainright, MO | 134 | Chillicothe, MO | 1,260 |
| Morrison, MO | 427 | Pattonsburg, MO | 3,630 |
| Gasconade, MO | 850 | Gallatin, MO | 615 |
| Rhineland, MO | 1,031 | Bethany, MO | 300 |
| Loutre Junction, McKittrick, MO | 203 | Total Grand River | 6,093 |
| Hermann, MO | 2,570 | Platte River | |
| Washington, MO | 483 | Agency, MO | 762 |
| Labadie, MO | 2 | Tracy, MO | 90 |
| Berger, MO | 114 | Total Platte River | 852 |
| Marthasville, MO | 586 | Blue River, Turkey & Indian Creeks | |
| Peers, MO | 179 | Kansas City, MO | 18,950 |
| Dutzow, MO | 30 | Kansas City, KS | 3,200 |
| Maryland Heights, MO | 7,300 | Merriam, KS | 1,420 |
| Chesterfield, MO | 227,323 | Kansas City MetroTotal | 23,570 |
| St. Charles, MO | 33,491 | 102 River | |

## Table 21
## Urban Damages

| Urban Area | Damage ($1,000) | Urban Area | Damage ($1,000) |
|---|---|---|---|
| Rosendale, MO | 842 | Edwardsville, KS | 70 |
| Barnard, MO | 69 | KCK, Muncie, Turner, KS | 15,658 |
| Total 102 River | 911 | Total Kansas River | 21,251 |
| Fishing River | | Big Blue River | |
| Excelsior Springs, MO | 12,000 | Marysville, KS | 413 |
| Richmond, MO | 360 | Centralia, KS | 1 |
| Total Fishing River | 12,360 | Staplehurst, NE | 1,000 |
| Nodaway River | | Seward, NE | 10 |
| Skidmore, MO | 25 | Dewitt, NE | 20 |
| Total Nodaway River | 25 | Beatrice, NE | 175 |
| Kansas River | | Blue Springs, NE | 10 |
| Ogden, KS | 8 | Total Big Blue River | 1,629 |
| City of Manhattan, KS | 1,380 | Little Blue River | |
| Remainder, Riley Co. | 2,376 | Morrowville, KS | 3 |
| Manhattan, KS, vicinity Pottawatomie Co. | 144 | Haddam, KS | 425 |
| Willard, KS | 26 | Greenleaf, KS | 1 |
| Valencia, KS | 38 | Total Little Blue River | 429 |
| Topeka, KS | 6 | Saline River | |
| Eudora, KS | 126 | Beverly, KS | 190 |
| Lawrence, KS | 1,048 | Tescott, KS | 288 |
| Lawrence, KS vicinity | 324 | Culver, KS | 25 |
| Paxico, KS | 6 | Lucas, KS | 7 |
| Wabaunsee, KS | 1 | Paradise, KS | 135 |
| Eskridge, KS | 1 | Natoma, KS | 1,044 |
| Bonner Springs, KS | 40 | New Cambria, KS | 9 |

**Table 21**
**Urban Damages**

| Urban Area | Damage ($1,000) | Urban Area | Damage ($1,000) |
|---|---|---|---|
| Total Saline River | 1,698 | Total Smoky Hill River | 762 |
| Solomon River | | Republican River | |
| Osborne, KS | 6 | Junction City, KS | 250 |
| Cawker City, KS | 40 | Wakefield, KS | 40 |
| Beloit, KS | 10 | Clifton,Vining, KS | 50 |
| Total Solomon River | 56 | Morgansville, KS | 77 |
| Smoky Hill River | | Concordia, KS | 5 |
| Salina, KS | 46 | Scandia, KS | 10 |
| Junction City, KS | 391 | Colby, KS | 1 |
| Abilene, KS | 47 | Total Republican River | 433 |
| Chapman, KS | 5 | Nemaha River | |
| Solomon, KS | 31 | Seneca, KS | 14 |
| Enterprise, KS | 72 | Total Nemaha River | 14 |
| Ellsworth, KS | 170 | Total Urban Damages | 661,041 |

3. Public Sector Damages

Damages to the public sector primarily fall into two categories. The first is damage to highways, bridges, and roads, including structural damage and losses from traffic delays and detours. The second category is damage to public utilities, particularly water supply facilities and wastewater treatment plants. The Federal Emergency Management Agency and Damage Survey Reports were the principal sources for this information. Table 22 summarizes public sector damages.

**Table 22**
**Public Sector Damages**

| State | Damage ($1,000) |
|---|---|
| Missouri | 191,470 |
| Kansas | 75,705 |
| Iowa | 2,845 |
| Nebraska | 3,982 |
| Total | 274,002 |

4. Levee Damages

Although all of the Federal urban local protection levees in the District held during the flood, most of them needed at least minor repairs, as did 9 of 15 MRLS levees. The total cost of repairing Federal levees in the District currently is estimated at $41.9 million. About two-thirds of this cost is due to major damage to three units: R-471-460, at Elwood, Ks.; L-246, at Brunswick, Mo.; and Lower Chariton, at Glasgow, Mo.

Repairs to non-Federal levees in the District are well underway. It is believed that repair costs for non-Federal levees in the District, including those levees not repaired by the Corps, will exceed $300 million.

5. Total Damages Sustained

Total damages within the District are estimated at more than $1.3 billion. Tables 23 and 24 total the damages by state and by category.

**Table 23**
**Total Damages by State**

| State | Damage ($1,000) |
|---|---|
| Missouri | 966,650 |
| Kansas | 285,875 |
| Iowa | 6,345 |
| Nebraska | 35,633 |
| Total | 1,294,503 |

**Table 24**
**Total Damages by Category**

| Category | Damage ($1,000) |
|---|---|
| Residential | 112,467 |
| Commercial | 548,574 |
| Public | 274,002 |
| Crops | 359,460 |
| Total | 1,294,503 |

## C. Flood Damages Prevented by Federal Projects

Damages prevented during the March-August 1993 flood event totaled $13.7 billion. More than half of this amount was in Missouri, and more than 99 percent was in Kansas and Missouri. Table 25 summarizes the damages prevented by major project category, and Table 26 summarizes the data by state for the March-August 1993 flood event.

**Table 25**
**Federal Project Damages Prevented by Category**

| Category | March-August 1993 Damages Prevented ($1,000) |
|---|---|
| MO River Main Stem Lakes | 3,772,093 |
| KCD Lakes | 4,007,316 |
| MO River Levee System | 188,275 |
| Local Protection Levees | 4,663,629 |
| Bureau of Reclamation Projects | 1,039,752 |
| Total KCD Damages Prevented | 13,672,355 |

**Table 26**
**Federal Project Damages Prevented - by State**

| State | March-August 1993 Damages Prevented ($1,000) |
|---|---|
| Missouri | 9,239,136 |
| Kansas | 4,430,788 |
| Nebraska | 1,079 |
| Iowa | 708 |
| Total KCD | 13,672,355 |

1. Reservoirs

District lakes prevented an estimated $4 billion in damages. Table 27 summarizes damages prevented by District lakes during the 1993 Flood from March-August.

**Table 27**
**Kansas City District Corps Lakes - Damages Prevented**

| Project Lake | Damages Prevented ($1,000) |
|---|---|
| Clinton (KS) | 232,690 |
| Harlan County | 46,878 |
| Hillsdale (KS) | 742 |
| Kanopolis (KS) | 711,510 |
| Little Blue River (MO) | 0 |
| Long Branch (MO) | 445 |
| Melvern (KS) | 17,549 |
| Milford (KS) | 286,748 |
| Perry (KS) | 858,887 |
| Pomme de Terre (MO) | 296 |
| Pomona (KS) | 23,369 |

**Table 27**
**Kansas City District Corps Lakes - Damages Prevented**

| Project Lake | Damages Prevented ($1,000) |
|---|---|
| Rathbun (IA) | 4,434 |
| Smithville (MO) | 36,401 |
| Stockton, MO) | 845 |
| Truman (MO) | 18,797 |
| Tuttle Creek (KS) | 1,247,829 |
| Wilson (KS) | 518,897 |
| Total | 4,007,316 |

2. Local Protection and MRLS Levees

Local protection projects, including those at Kansas City and Topeka, prevented an estimated $4.664 billion in damages. Table 28 summarizes damages prevented by local protection projects in the Kansas City District. Levees in the Missouri River Levee System (MRLS), which primarily protect agricultural land, prevented an estimated $188 million in damages. Table 29 lists damages prevented by Missouri River Levee System units during March-August of 1993..

**Table 28**
**Corps Local Protection Levees - Damages Prevented**

| Local Protection Project | Damages Prevented ($1,000) |
|---|---|
| Argentine (K. C.), KS | 514,694 |
| Armourdale (K. C.), KS | 217,521 |
| Auburndale (Topeka), KS | 759 |
| Birmingham (K. C.), MO | 42,515 |
| C.I.D. (K. C.), MO | 192,754 |
| East Bottoms (K. C.), MO | 651,129 |
| Fairfax (K. C.), KS | 1,987,666 |
| Lawrence, KS | 4,957 |

## Table 28
## Corps Local Protection Levees - Damages Prevented

| Local Protection Project | Damages Prevented ($1,000) |
|---|---|
| Manhattan, KS | 12,393 |
| New Haven, MO | 647 |
| North Kansas City (K. C.), MO | 966,651 |
| North Topeka (Topeka), KS | 38,065 |
| Oakland (Topeka), KS | 5,185 |
| Osawatomie, KS | 177 |
| Ottawa, KS | 2,087 |
| Salina, KS | 12,520 |
| South Topeka (Topeka), KS | 13,911 |
| Total | 4,663,629 |

Note: No data were available concerning damages prevented by the following local protection levees: Barnard, NE; Bartley, NE; Bedford, IA; Chariton River, MO; Clyde, KS; Fairbury, NE; Frankfort, NE; Indianola, NE; Little Blue River Channel, MO; Seward, NE; Stonehouse Creek, KS; and Stranger Creek, KS.

## Table 29
## Corps MRLS Levees - Damages Prevented

| MRLS Levee | Damages Prevented ($1,000) |
|---|---|
| R-513-512 | 1,079 |
| R-500 | 77 |
| L-497 | 1,032 |
| L-488 | 425 |
| R-482 | 269 |
| L-476 | 837 |
| R-471-460 | 667 |

## Table 29
## Corps MRLS Levees - Damages Prevented

| MRLS Levee | Damages Prevented ($1,000) |
|---|---|
| L-455 | 175,870 |
| L-448-443 | 1,931 |
| R-440 | 701 |
| L-408 | 1,145 |
| L-400 | 268 |
| R-351 | 884 |
| L-246 | 1,955 |
| Lower Chariton | 1,164 |
| Total | 188,275 |

3. Protective Emergency Measures

Damages prevented by protective emergency actions in advance of the flooding are still being determined. While advance warnings of flooding allowed time to move items to higher ground in many communities, this opportunity often was negated by two factors: (1) flood hit sites which had never been flooded before, and many people ignored the warnings for this reason; and (2) flood depths were much greater and reached much higher ground than most people expected, often inundating items which had been moved in advance.

4. Stage Reductions

Table 30 summarizes estimated stage reductions due to Federal flood control lake projects at each gage station along the major rivers.

## Table 30
## Stage Reductions from all Federal Projects

| Gage Location | River | Reduction (Ft.) |
|---|---|---|
| St. Joseph, MO | Missouri | 1.8 |
| Kansas City, MO | Missouri | 3.3 |
| Waverly, MO | Missouri | 3.2 |
| Boonville, MO | Missouri | 3.3 |
| Hermann, MO | Missouri | 2.9 |
| Moulton, IA | Chariton | 5.4 |
| Prairie Hill, MO | Chariton | 2.4 |
| Macon, MO | Little Chariton | 6.9 |
| Ottawa, KS | Osage | 5 |
| State Line | Osage | 2.4 |
| Schell City, KS | Osage | 3.4 |
| St. Thomas, KS | Osage | 15.6 |
| Smithville, MO | Little Platte | 2.1 |
| Ft. Riley, KS | Kansas | 7.1 |
| Manhattan, KS | Kansas | 2.9 |
| Wamego, KS | Kansas | 1.6 |
| Topeka, KS | Kansas | 2.2 |
| Lecompton, KS | Kansas | 2.3 |
| Desoto, KS | Kansas | 4.5 |
| Ellsworth, KS | Smoky Hill | 0.9 |
| Mentor, KS | Smoky Hill | 4.9 |
| New Cambria, KS | Smoky Hill | 2.9 |
| Enterprise, KS | Smoky Hill | 6.5 |
| Tescott, KS | Saline | 2.8 |
| Niles, KS | Solomon | 5.4 |
| Concordia, KS | Republican | 0.4 |
| Clay Center, KS | Republican | 0.4 |

## XI. Post Flood Recovery Activities

When the FEMA Missouri Disaster Field Office (DFO) made the transition from response to recovery on 19 August, the District was actively involved in Interagency Levee Rehabilitation coordination, performing the Damage Survey Report (DSR) mission and the ESF #3 missions for technical assistance, water supply support, and providing a water truck for a mobile kitchen.

The Kansas FEMA DFO made a direct mission assignment to the District, under Public Law 93-288, for emergency removal of debris on public and private property in Elwood, Kansas. Two household debris removal contacts were issued for the removal of sediment and the removal of freon from appliances. Major quantities of sediment were removed from the streets of Elwood and the large drifts located on private property that impeded the recovery efforts of citizens.

In addition, the District supported FEMA with inspectors to prepare Damage Survey Reports in both Kansas and Missouri.

### A. PL 84-99 Levee Rehabilitation

On 23 August 1993, following the activation of the District Rehabilitation Assistance Center (RAC) and a cursory assessment of the levee damage, a Rehabilitation Plan was completed. Development of the plan was in support of the ongoing rehabilitation operation.

A total of 51 Federal levee sections were damaged. This is all of the Federal levee sections in the District's area of responsibility. Only 27 sections sustained damages of a magnitude requiring PL 84-99 rehabilitation assistance beyond normal maintenance.

The event damaged nearly all non-Federal levees on the Missouri, Kansas, Grand, Platte, Chariton and Osage Rivers. In addition, there were damaged levees on other tributaries too numerous to mention. In all, over 800 levee segments were damaged. Of this number, only 110 units were eligible for PL 84-99 assistance prior to the flood event.

Teams of engineers, technicians, surveyors, archaeologists, environmentalists, and biologists were assembled to make the field investigations, including identifying borrow sites from which the dirt and clay could be borrowed to use as fill for the breaches. Care was taken so that no historic sites would be disturbed and that environmental damage would be minimized.

Levee districts experienced difficulty in getting landowners to agree to easements for areas where levees had to be moved back onto their land. Much of the damage caused such large holes that it was more economically feasible to go around the holes, eating up more precious farmland. Levee districts also had to provide their portion of the cost share with either cash outlay or in-kind work. This was a hardship on many in that the cash or work was assessed on those who had lost not only their livelihood but their homes as well.

Rehabilitation efforts were administered by a combination of District, temporary duty, and Bureau of Reclamation personnel. Several circumstances adversely affected the rapid response efforts of the Corps of Engineers and field investigations progressed very slowly. Persistent rain kept many of the levees under water, making it impossible for the inspection teams to survey the damage.

Wet ground conditions took their toll not only on the inspection process, but personnel as well. Personnel worked seven days a week, sunrise to sunset, under adverse conditions, including remote locations, mud, insects, snakes, inclement weather, and total physical exhaustion. After survey teams spent several days doing the investigation, the river would rise again and additional damages were incurred and the team had to return to the site. Although the use of all terrain vehicles (ATVs) was most valuable in getting to many of the areas, they were not the panacea.

Massive realignments and costly local cost share portions caused delays and frustration for both the District and landowners. Requirements for legal descriptions, rights of way, easements and the up-front cost share caused a greater impact on the levee boards than anticipated. This was the first major test of the 1986 rule change and the District's partnership with levee districts. The results of this partnership has resulted in increased investigation and alternative development costs.

## B. Interagency Coordination

While the District's efforts were concentrated on the flooding and PL 84-99 repairs of levees, as the lead District in the states of Missouri and Kansas, it also supported the interagency coordination and review of levee repair projects.

In early August, the Federal Levee Rehabilitation Task Force established the need for interagency coordination within the Disaster Field Office. The concept was to provide a central focal point for quick review of all levee rehabilitation applicants and allow for consistent policy adherence among the affected states. In addition, the memorandum from the Executive Office of the President, Office of Management and Budget, dated 23 August 1993, provided additional guidance for ensuring that all relevant organizations had an opportunity to comment on projects, and offer other alternatives to levee restoration. The overall goal was to achieve a rapid and effective response to the damaged flood control system that would minimize risk to life and property, ensure a cost-effective approach to flood damage mitigation and floodplain management, and protect important environmental and natural resource values.

Initially, FEMA made a mission assignment to the Corps to develop a data base of all known levees in the State of Missouri capable of being used by the three primary agencies, Corps of Engineers, Soil Conservation Service (SCS), and FEMA. This portion of the mission was completed in less than two weeks with over 800 levees entered in the data base. It has since grown to over 1,400 levee entries.

The Federal Coordinating Officer notified all ineligible levee sponsors, (enclosing brochures from the Corps of Engineers, SCS, Fish and Wildlife Service (FWS) and Environmental Protection Agency (EPA) regarding their various programs), that no Federal assistance was available for repairing their levee.

### C. Flood Fight Preparation Plan

The ultimate goal of the Kansas City District was to expedite repair of all eligible levees to their pre-disaster condition. Numerous factors made it evident that all units would not be repaired prior to the spring flood season. Therefore, steps were initiated to prepare for the worst case scenario in the event the river floods again in the spring of 1994.

Some of the preparation included states identifying the most critical areas where flood fighting might be necessary, planning for rapid closure of previously damaged levees, conducting flood fight training and other actions necessary to place the District in a readiness posture.

## XII. Lessons Learned

### A. General

The Flood of 1993 tested the District's resources to a measure that had not been experienced since the 1951 flood. Obviously, there was no staff with experience in dealing with a flood of this magnitude. Consequently, the District staff was on an accelerated learning curve as the flood event developed. This was necessary and appropriate because it is not practicable to have every possible need covered for events that occur once each generation. The 1993 Flood demonstrated that the District staff, when put to the test, will respond with its professional skills and personal dedication day after day, week after week, and month after month, until the emergency condition no longer exists. A most obvious lesson learned is the value in having the District's resources available to respond to the emergency. Other lessons learned which follow were derived from the listing of issues identified by the District staff.

### B. Emergency Operations Center

A comprehensive evaluation of the EOC should be undertaken. The study should identify physical arrangements and equipment acquisition that should be implemented.

Particular attention should be given to the communication and computer technological needs.

The EOC operation and reporting procedures should be reviewed with a view toward a more efficient operation and standardization of procedures.

Technical information required for the support of the EOC should be examined to assure completeness and availability. Also, suggestions for improving the technical support information should be pursued.

### C. Reservoir Operations

The experience gained from operating several projects near or above full flood control should be closely examined and documented for use in developing future operation plans. This information should be shared with other Districts having similar projects.

### D. Preparation/Training

Several suggestions were made to improve reporting procedures and to improve readiness capability. Based on the number of suggestions regarding training, there is an apparent need for increased training in nearly every facet of the emergency operation.

### E. Personnel

With the District already in a period of stress-filled adjustment to a changing workload, the manpower demands created by the flood added to the pressure. Several of the suggestions related to personnel would exacerbate manpower limitations. Suggestions regarding personnel need to be carefully reviewed.

### F. Equipment

Equipment needs identified were relatively limited. However, justification for some of the equipment will require careful analysis.

### G. Levee Rehabilitation

The PL 84-99 program requires Command attention in order to accomplish its purpose. Suggestions to make the program more efficient and responsive should be implemented.

## Glossary

**Acre-foot:** An area of one acre covered with water to a depth of one foot. One acre-foot is 43,560 cubic feet or 325,851 gallons.

**Aggradation:** A modification of the earth's surface in the direction of uniformity of grade by deposition.

**Agricultural levee:** A levee that protects agricultural areas from floods, but the degree of protection is usually for more frequent flood events.

**Appropriation:** The setting aside of money by Congress, through legislation, for specific use.

**Authorization:** House and Senate Public Works Committee resolutions or specific legislation which provide the legal basis for conducting studies or constructing projects. The money necessary for accomplishing the work is not a part of the authorization, but must come from an appropriation by Congress.

**Bank and channel stabilization:** The process of preventing bank erosion and channel degradation.

**Basin:** (1) Drainage area of a lake or stream as: river basin. (2) A naturally or an artificially enclosed harbor for small craft as: yacht basin.

**Blew Hole:** A large scour hole created when flood waters overtop and breach a levee.

**Breach:** A broken or ruptured condition often used to describe a break in a levee.

**Closure structure:** A structure built along low points of a levee or floodwall such as a street or railroad intersection to prevent floodwaters from flooding the area protected by the levee or floodwall.

**Confluence:** The place where two streams or rivers converge into a single stream or river.

**Critical Dam Surveillance:** When the flood control pool reaches the 50-year pool level (a pool level that should happen on the average once every 50-years) or the flood control pool reaches a record high pool, the entire length of the dam embankment and toe of the dam will be checked and piezometers read daily or twice daily. The surveillance will vary from project to project.

**Dam:** A barrier constructed across a valley for impounding water or creating a reservoir.

**Damages Prevented:** The difference between damages occurring without the project and the damages with the project in place.

**Degree of protection:** The magnitude of flooding that a flood control measure is designed for, usually expressed as a statistical estimate of how often such a flood would occur, i.e., " a 100-year flood" .

**Dike:** An embankment to confine or control water, and/or soil. See also Levee.

**Draft:** The vertical distance from the waterline to the bottom of a floating vessel.

**1% Flood:** This is the same as a 100-year flood and is a flood which has a 1% chance of occurring during any given period.

**Foreshore:** A strip of land margining a body of water.

**Flood capacity:** The flow carried by a stream or floodway at bank-full capacity. Also, the storage capacity of the flood pool in a lake or reservoir.

**Flood crest:** The highest or peak elevation of the water level during a flood in a stream or river.

**Floodplain:** Valley land along the course of a stream which is subject to inundation during periods of high water that exceed normal bankfull elevation.

**Floodwall:** Wall, usually built of reinforced concrete, to confine streamflow to prevent flooding.

**Freeboard:** (1) The vertical distance from the water surface to the top of a protective structure. (2) An allowance in protection above the design water surface level.

**Froude number:** The ratio of the inertia forces to the gravity forces ($V/(gL)^{1/2}$). Systems involving gravity and inertia forces include the flow of water in open channels, the forces of a stream on a bridge pier, and the flow over a spillway.

**Headwaters:** (1) The extreme upper reaches of a stream near its source. (2) The region where groundwaters emerge to form a surface stream. (3) The water upstream from a structure.

**Hydrostatic:** Related to the pressures exerted or transmitted by liquids at rest.

**Increased Surveillance:** When the flood control pool reaches the 5-year pool level (a pool level that should happen on the average once every 5-years), the entire length of the dam embankment and toe of the dam will be checked and piezometers read weekly. The surveillance will vary from project to project.

**Left or right bank of river:** The left-hand or right-hand bank of a stream when the observer faces downstream.

**Levee:** A dike or embankment, generally constructed close to the banks of a stream, lake, or other body of water, intended to protect the landslide from inundation or to confine the streamflow to its regular channel.

**Meander:** The name given to the winding course of a stream or river.

**Mouth of river:** The exit point of discharge of a stream into another stream, a lake, or the sea.

**Oxbow lake:** A lake formed in an old meander of a stream as a result of a channel cut-off by either natural necking down of a meander loop or by man.

**Piezometer:** An instrument for measuring the change of pressure of a material subjected to hydrostatic pressure.

**Ponding area:** A storage area reserved for collecting excess runoff preparatory to being discharged either by gravity or by pumping.

**Pool:** A small and rather deep body of quiet water as: water behind a dam.

**Reach:** A length or distance along a watercourse between two geographical locations or sites.

**Recurrence interval:** The statistically derived probability of occurrence of a flood event, converted to a time interval (e.g. a 1% chance flood = 100-year flood (1/.01).

**Rehabilitation:** A major repair job. Usually involves considerable reconstruction of already existing structures.

**Reservoir:** A pond or lake, either natural or created by the building of a structure such as a dam, which is used for storage, regulation, and control of water for power, navigation, recreation, etc.

**Revetment:** (1) A facing of stone, concrete, sandbags, etc., to protect a bank of earth from erosion. (2) A retaining wall.

**Riprap:** A layer, facing, or protective mound of randomly placed stones to prevent erosion, scour, or sloughing of a structure or embankment. The stone so used for this purpose is also called riprap.

**River basin:** The tract of country drained by a river and its tributaries.

**Sediment load:** The natural inorganic soil materials composed of suspended load and bed load transported by a stream. The suspended load is composed of fine sediment transported in suspension while the bed load is composed of relatively coarse material transported along or near the bottom (bed) of the stream.

**Sill:** A low, submerged, dam-like structure built to control riverbed scour and current speeds.

**Spillway:** A waterway of a dam or other hydraulic structure used to discharge excess water to avoid overtopping of a dam.

**Stage:** The elevation of the water surface above or below an arbitrary datum.

**Standard project flood:** A flood that may be expected from the most severe combination of meteorological and hydrological conditions that are reasonably characteristic of the geographical region, excluding extremely rare combinations of events.

**Tainter Gate:** A semi-circular gate which opens and closes through pivoting on a shaft and is used to control the flow of water over spillways.

**Thalweg:** A line following the lowest part of a channel.

**Tributary:** A stream or other water course that contributes its water to another stream or water course.

**Uncontrolled spillway:** A spillway that has no gated control.

**Watershed:** The whole geographical surface area that drains excess rainfall and contributes the water to a collecting river or lake.

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